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Dipartimento di Biologia
Sezione di Geobotanica ed Ecologia vegetale
Università di Trieste

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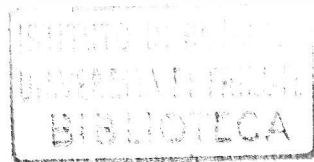
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I-34100 TRIESTE (Italy).

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THE VEGETATION IN THE DOLINAS OF THE KARST REGION NEAR TRIESTE (ITALY)

Dario FAVRETTO & Livio POLDINI **

Keywords: Karst, dolinas, vegetation, geomorphology, Trieste (NE Italy).

Abstract: On the basis of an ecological model the relationships between the vegetation and geomorphology of the dolinas are described for the Karst region near Trieste. Observations about presence thresholds of primary coenoses and the classification of dolinas, according to vegetation are made.

Introduction

For some time geobotanists have been studying dolinas (sink-holes) and hollows in general, because of the profound changes they bring about in the local climate. Mention should be made of the now classical studies published by Beck (1906) and Horvat (1953) and more recently, by Polli (1961) and by Poldini and Toselli (1982). The type of hollow known as the dolina was selected because it offers suitable data for the study of the relationship between vegetation and geomorphological features. In the fact the dolina, as a hollow, enriches and is a factor of diversification in the environment. Morphological discontinuity of an exclusively physical nature has a selective role in the organisation of flora into types of vegetation and their synthesis. The objective of this study is to investigate:

1. the ecology of the coenoses by the indirect method (Whittaker 1978)
2. the relationship between geomorphological discontinuity (Dg) * and vegetational diversity (Dv) and thus the role of dolinas in increasing the landscape diversity;
3. the classification of dolinas according to vegetation.

1. Data and methods

A strip of the Karst region near Trieste with a particularly high concentration of dolinas was chosen for this study. 63 dolinas were considered to constitute a sample which would adequately represent their variability. The local conditions (geomorphological features) taken into consideration were the following: depth,

* The term "discontinuity" is used here to refer to the sharp variations produced by dolinas on abiotic variables, which are used in this study to identify the geomorphology of the area under investigation (ecotone variations).

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rockness, volume, form, orientation, eccentricity and potential as agricultural land or pasture.

Pedological features and height above sea level were not taken into consideration as both are constant in the area under examination.

To analyse the relationship between coenoses and geomorphological features a representative model of the dolina was created taking into account the total vegetation inside, represented by a presence/absence table of individual coenoses and the seven geomorphological features mentioned above.

The coenoses found in the dolinas must be divided into two groups:

A : *Secondary coenoses*, listed below in descending order of intensity of use:

Intensity of use	Culture and Pastures	Post-Culture Vegetation	Hedges
I High	- Robinia woods	10 - Groupings of <i>Lamium orvala</i> and <i>Sambucus nigra</i>	—
II Medium	11 - <i>Arrhenatheretum brometosum erecti</i> 12 - <i>Arrhenatheretum holcetosum lanatis</i> (MEADOWS)	6 - <i>Brachypodio - Agropyretum intermedii</i>	—
III Weak	4 - <i>Danthonio - Scorzonertum cirsietosum pannonicici</i>	3 - <i>Prunus spinosa</i> shrubs	—
IV Low	5 - <i>Chrysopogono - Centaureetum cristatae</i> (PASTURES)	—	8 - <i>Corno-Ligustretum illyricum</i> (*)

Table 1 — Secondary coenoses, listed in descending order of intensity of use.

B: *Primary coenoses*:

1. *Galantho-Coryletum*
2. *Ostryo-Quercetum pubescentis*
7. *Seslerio-Quercetum petraeae*
9. *Asaro-Carpinetum*

Description of geomorphological features

1. Depth *P* - the difference between the height of the highest contour line (outer rim) and the height of the floor, in metres.
2. Rockiness *R* - conventional measurement on a scale from 0 (absence) to 4 (vertical walls). In the area under examination the dolinas are rocky only on north-facing slopes.
3. Volume *V* - given by the product of $A \times a \times P$, where *A* is the major axis and "a" the minor axis, of the figure formed by the highest contour line circumscribing the dolina. Measured in cubic metres.

(*) The name suggested by Horvat (1956, 1974) has been provisionally adopted. The table for this coenose is in fact poorly identified in terms of characteristic or differential species. The samples taken on the Karst and in Friuli are well differentiated both from the central European *Viburno-Ligustretum* and from Horvat's *Corno-Ligustretum* by *Rubus ulmifolius* and by *Peucedanum venetum*.

4. Form F - this factor (F_{ok}), which represents the degree of geometrical "regularity" of the dolina, is quantified by four parameters:
 A and a , as in point 3 above
 P depth
 D , the horizontal distance between the deepest point and the centre of the shape described by the highest contour line. The measurement is given by:

$$F_{ok} = \frac{\sqrt{2} - S_{ok}}{\sqrt{2}}$$

where S_{ok} is the normalised euclidean distance between point $B_k(A, a, D, P)$ representing a generic dolina, and point $B_o(A, A, O, A/2)$ representing a regular geometric form for reference. The result is therefore $0 \leq F_{ok} \leq 1$. High F values correspond to dolinas which are near to hemispherical in form.

5. Orientation S $S_k = 1 + \cos \alpha_k$
 where α_k is the angle formed by the major axis A_k of the highest contour line and an east-west line.
 S provides a measurement of the solar energy entering the dolina. High S values correspond to dolinas, with a major axis close to an east-west direction, which receive the highest amount of solar heat.

6. Eccentricity E $E_k = 1 + \frac{2 D_k}{A_k}$
 A, D have already been described
 $D_k \text{ max} = \frac{A_k}{2} \quad 1 \leq E \leq 2.$

7. Potential U $U_k = \frac{G_k}{G_{max}}$ (relative value of potential)

where $G_k = \frac{A_k^l}{L_k^m (R_k + 1)^n}$ (absolute value of potential)

and G_{max} is the maximum value of G_k therefore $0 \leq U \leq 1$.
 A and R have already been described; L is the distance, by path or road, from dolina to the nearest location with agricultural activity or pasture. A, L and R are of different weight in the quantification of U .

$$l = 1,2 \quad ; \quad m = 0,4 \quad ; \quad n = 0,8$$

The geomorphological features quantified for the 63 dolinas, as described, are arranged in classes whose extreme values are shown in the table 2.

GEOMORPHOL. FEATURES	UNIT OF MEASUREMENT	VALUES MEASURED	
		MIN	MAX
<i>P</i>	metres	4	59
<i>R</i>	—	0	4
<i>V</i>	10 ³ cubic metres	4	12.036
<i>F</i>	—	0.58	0.90*
<i>S</i>	—	1	2*
<i>E</i>	—	1.00	1.82*
<i>U</i>	—	0.02	1.00*

Table 2 — Extreme values of the geomorphological features.

The dolinas as physical entities may now be represented by a group of seven parameters with values comprised in the classes mentioned above. For reasons of uniformity, however, and because of the demands of successive elaborations, it was considered appropriate to use for each of the seven features, four classes of values, instead the numerical values obtained:

Classes

- | | |
|------------------------|-----------------------------|
| 1 - low values | from MIN to Medium Low (Mb) |
| 2 - medium low values | from Mb to Medium (M) |
| 3 - medium high values | from M to Medium High (Ma) |
| 4 - high values | from Ma to MAX |

The numerical values of the levels which define each class, for each feature, are shown in the table 3.

LEVEL FEATURE	MIN	Mb	M	Ma	MAX
<i>P</i>	4	9	13	22	59
<i>R</i>	0	0.5	1.2	2.4	4.0
<i>V</i>	4	93	476	3110	12.036
<i>F</i>	0.58	0.71	0.77	0.81	0.9
<i>S</i>	1.00	1.12	1.55	1.80	2.00
<i>E</i>	1.00	1.14	1.23	1.41	1.82
<i>U</i>	0.02	0.07	0.16	0.30	1.00

Table 3 — Values of the class levels.

The numbers of dolinas considered according to class of values and to feature is shown in the table 4.

(*) the values measured are found inside the fields of variability:

$$0 \leq F \leq 1; \quad 1 \leq S \leq 2; \quad 1 \leq E \leq 2; \quad 0 \leq U \leq 1$$

CLASS FEATURE	1	2	3	4	TOTAL
<i>P</i>	20	22	14	7	63
<i>R</i>	19	22	15	7	63
<i>V</i>	35	20	5	3	63
<i>F</i>	13	12	23	15	63
<i>S</i>	14	10	18	21	63
<i>E</i>	15	28	14	6	63
<i>U</i>	22	17	17	7	63

Table 4

In order to be able to represent the dolina in the form of a model also from the point of view of geomorphological discontinuity, it should be pointed out that this discontinuity is proportional:

- directly to the depth *P*
- inversely to the surface *B* of the mouth, given by the product of the lengths of the two axes $A \times a$
- directly to parameter *C*, which gives the measure of deviation of the mouth from a circular form, given by the proportion $\frac{A}{a}$.

Therefore, taking account of the preponderant weight of *P* compared to the other factors, we may write:

$$Dg = P^2 \frac{C}{B}$$

$$\text{where } C = \frac{A}{a} \quad \text{and} \quad B = A \cdot a$$

the result is:
$$Dg = \left(\frac{P}{a} \right)^2$$

The function *Dg* will be used later in the analysis of his connections with the vegetational diversity.

The calculations of the clustering are described by Feoli E., Lagonegro M. and Zampar A. (1982).

2. Results

Before the correlations between vegetation and morphology are examined, some statistical data expressing the average characteristics of the sample are presented below. The relative frequency of dolinas in terms of classes of values of geomorphological features, derived from table 4 is represented in the table 5.

FEATURE \ CLASS	1	2	3	4
<i>P</i>	31	36 *	22	11
<i>R</i>	30	35 *	24	11
<i>V</i>	57 *	33	6	4
<i>F</i>	22	19	37 *	22
<i>S</i>	22	16	28	34 *
<i>E</i>	23	46 *	22	9
<i>U</i>	35 *	27	27	11

Table 5

* Maximum frequency

The arrangement of dolinas in classes of geomorphological features shows that in the sample the most frequent dolinas are small (max in *V1*), of low potential (max in *U1*), with a high *S* (max in *S4*), but with *P*, *R*, *F* and *E* in the medium low and medium high classes.

The most likely dolina from a geomorphological point of view is therefore:

GEOMORPH. FEATURES	CLASS
<i>P</i>	2
<i>R</i>	2
<i>V</i>	1
<i>F</i>	2
<i>S</i>	4
<i>E</i>	2
<i>U</i>	1

The relative frequency distribution of dolinas, in terms of the number of coenoses they contain, is represented in the following graph (Fig. 1).

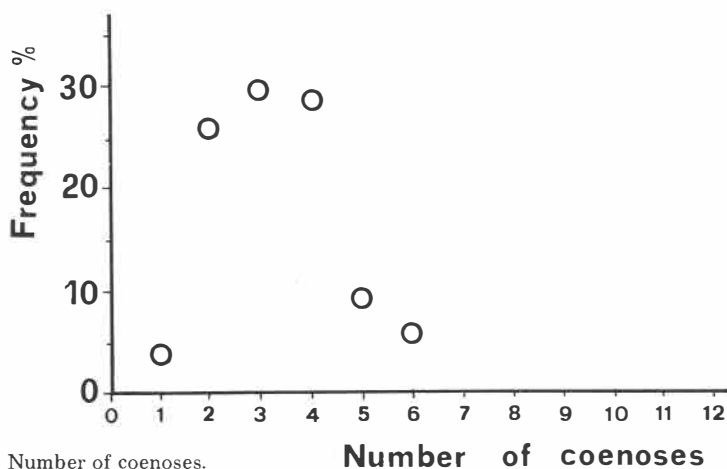


Fig. 1 — Number of coenoses.

The maximum frequency (29%) was of dolinas with 3 coenoses. No dolina was found to have more than 6 coenoses.

Finally, table 6 presents the maximum frequencies of coenoses according to geomorphological features represented in the matrix of the most favourable ecological conditions.

This table, was obtained from seven matrices, (one for each geomorphological feature, which, for the purposes of simplicity, do not appear in the text) each having 12 rows (coenoses) and 4 columns (classes of values of the geomorph. features) whose elements represent the relative frequency of the dolinas. By selecting the maximum values of the elements in these matrices, we obtain a synthetic representation of the most favourable ecological conditions for the 12 coenoses.

COE- NOSES	GEOMOPHOLOGICAL FEATURES						
	<i>P</i>	<i>R</i>	<i>V</i>	<i>F</i>	<i>S</i>	<i>E</i>	<i>U</i>
1 ☐	4	4	4	4	1	1	1
2 ☐	4	1	4	2	1	3	2
3	4	1	4	3	3	3	4
4	1	1	4	1	2	3	2
5	4	3	4	4	2	3	4
6	4	2	2	2	3	1	4
7 ☐	4	2	4	2	2	2	4
8	2	2	3	1	1	2	4
9 ☐	3	3	4	4	2	1	1
10	1	4	2	3	1	4	2
11	2	1	3	1	1	2	3
12	2	1	2	3	1	2	3

☐ Primary coenoses.

Table 6 — Matrix of the most favourable ecological conditions. It may be deduced from this table that, for example, coenose 1 is most frequent in dolinas, if they exist, with values of class 4 for features *P*, *R*, *V* and *F* and of class 1 for features *S*, *E* and *U*.

We can now analyze the relationship between coenoses and morphology which are derived from the seven matrices above mentioned.

Secondary coenoses

The presence of this group depends exclusively on intentional human intervention, which means that the search for a possible causal relationship with geomorphological features would not produce results of any significance. Some of the more important features of these coenoses, however, are pointed out below, in descending order of intensity of use (see Tab. 1).

It may be seen first that both primary and secondary coenoses are most frequent in large dolinas. This is because large dolinas are suitable for various types of agricultural use, and at the same time may possess several pedoclimatic en-

vironments.

I - Coenoses at a high intensity of use:

- Groupings of *Lamium orvala*, *Sambucus nigra* (10) and robinia woods.

These groupings, which derive from hoed cultures, are absent in dolinas of high potential, but present in those of low and medium potential; they are most frequent in the last of these categories. This may be explained by the supposition that dolinas of medium-low potential were the first to be abandoned and that in some cases this type of tree culture (robinia) which requires little maintenance and is used only occasionally, was chosen by man for dolinas of the most marginal agricultural utility.

II - Coenoses at a medium intensity of use:

- *Arrhenatheretum brometosum erecti* (11)
- *Arrhenatheretum holcetosum lanati* (12).

These are most frequent in small depressions, which are the most suitable for the maintenance of meadows. While on one hand a slight depression is suitable for mesophilous species, which have greater requirements than karstic pasture, a moderate difference in height does not impede fertilisation and collection of forage. These two coenoses are most frequent in dolinas of medium high potential U3. They are totally absent in dolinas of maximum depth, rockiness and volume.

- *Brachypodio - Agropyretum intermedii* (6)

This is a coenose deriving from previous hoed cultures. As was to be expected, its maximum frequency is in dolinas of high potential.

III - Coenoses at a weak intensity of use:

- *Danthonio - Scorzonetum cirsietosum pannonicum* (4)

This is represented by meadows and pasture; therefore observations made about coenoses 11 and 12 (meadows) partially apply. It is absent in dolinas of maximum rockiness, but present with a moderate maximum frequency in large dolinas (P4 and V4) and in those of maximum potential (U2, U3).

- *Prunus spinosa* shrubs (3)

As a result of its particular needs this species is found in cool and damp locations, with high maximums of frequency in dolinas of high potential, depth and volume. It is typical of postculture.

IV - Coenoses at a low intensity of use:

- *Chrysopogono - Centaureetum cristatae* (5)

This has a clear maximum frequency in dolinas of large dimensions (P4, V4) and of low rockiness (R1, R2). This may be explained by the fact that large dolinas have large slopes with a southern exposure, which man has turned into pasture. The concomitant maximum frequency of seminatural vegetation (2 and 7) may be understood in the light of the consideration that the north-facing slopes of these dolinas are just as extensive and rocky where man has kept woodland.

The dolinas most frequently used for pasture, as was to be expected, are those of the highest potential (U4).

- *Corno-Ligustretum coryletosum* (see note pag. 3)

The presence of this coenose is the result of stone clearance and the construction of cairns and perimeter walls in the dolinas. This environment is ideal for the formation of hedges. Its maximum frequency is consequently in dolinas of the highest potential (*U4*). Its total absence in dolinas of maximum rockiness does not stem from any ecological incompatibility - this coenose is in fact markedly lithophilous - but from the fact that a high degree of rockiness has prevented any agricultural use.

Primary coenoses

From the analysis of the data on semi-natural coenoses it may be observed that:

1 - *Galantho-Coryletum* (G-C)

Table 6, showing the most favourable ecological conditions, makes clear the preference of this coenose for large dolinas (*P4*, *V4*) of high rockiness (*R4*), regular form (*F4*) and low eccentricity (*E1*). Its frequency is not affected by the feature of orientation and potential. The maximum frequency of G-C in dolinas where coenose 3 is close to its maximum values may be explained by the fact that the pedoclimatic conditions which favour this coenose - cool and damp areas - are also ideal for G-C.

The maximum presence of G-C and 5 in large dolinas (*V4*) may be explained by the fact that, as happens in mountain areas, their south-facing slopes have been turned into pasture and the north-facing slopes have been kept wooded.

2 - *Ostryo-Quercetum pubescentis* (O-Q)

This is part of the zonal vegetation (climax) of the supramediterranean Karst. Its presence has nothing to do with any geomorphological features. It is limited to south-facing upper rims and is nothing more than part of the dominant vegetation penetrating in from the outside. In small dolinas this in fact is the only forest vegetation.

It should be pointed out that in this case, as in the case of G-C its preference for large dolinas, which are also where secondary coenoses are most frequent, may be explained by considering that they are the most suited to cultivation on south-facing slopes and on the floor, while on north-facing slopes conditions favour the conservation of nearly-natural vegetation.

7 - *Seslerio-Quercetum petraeae* (S-Q)

It must also be supposed in the case of S-Q that its maximum frequency in dolinas where secondary coenoses are also found is due to the suitability (mentioned above) of large dolinas for different types of cultivation on their south-facing slopes and floors and for the maintenance of trees on the opposite slopes.

As this is a semi-natural coenose its maximum frequency in dolinas of the highest level of potential may appear contradictory. This may be explained by considering that the pedoclimatic conditions (cool environment and deep soil) which encourage the establishment of S-Q are also ideal for agriculture.

The fact that S-Q is found less frequently with the other two primary coenoses than it is with the secondary types means that S-Q is the first of the extra-zonal types to establish itself in dolinas which retain conditions favourable for agriculture.

9 - *Asaro-Carpinetum* (A-C)

The maximum frequency of this coenose is in dolinas of depth $P3$ rather than in those of $P4$, as might have been expected. The dolinas of depth $P4$ in the sample under examination have very wide mouths, encouraging the movement of air from outside into the dolinas, impeding the establishment of A-C. In dolinas of depth $P3$ the relationship between mouth size and depth gives rise to the so-called "cold trap" in their deepest parts.

The geometrical relationships underlying this mechanism may be understood by reference to function Dg , geomorphological discontinuity, described above.

Once Dg has been calculated for each dolina in the sample, the distribution on the surface formed by axis Dg and axis P , as shown on the Figure 2 makes the following considerations possible:

- narrow and deep dolinas, suitable for A-C, are situated in the central part of the interval of variability of P and not at its highest point;
- the distribution of the dolinas containing A-C shows a precise threshold line for the values of Dg , below which are found only dolinas not containing A-C; the minimum

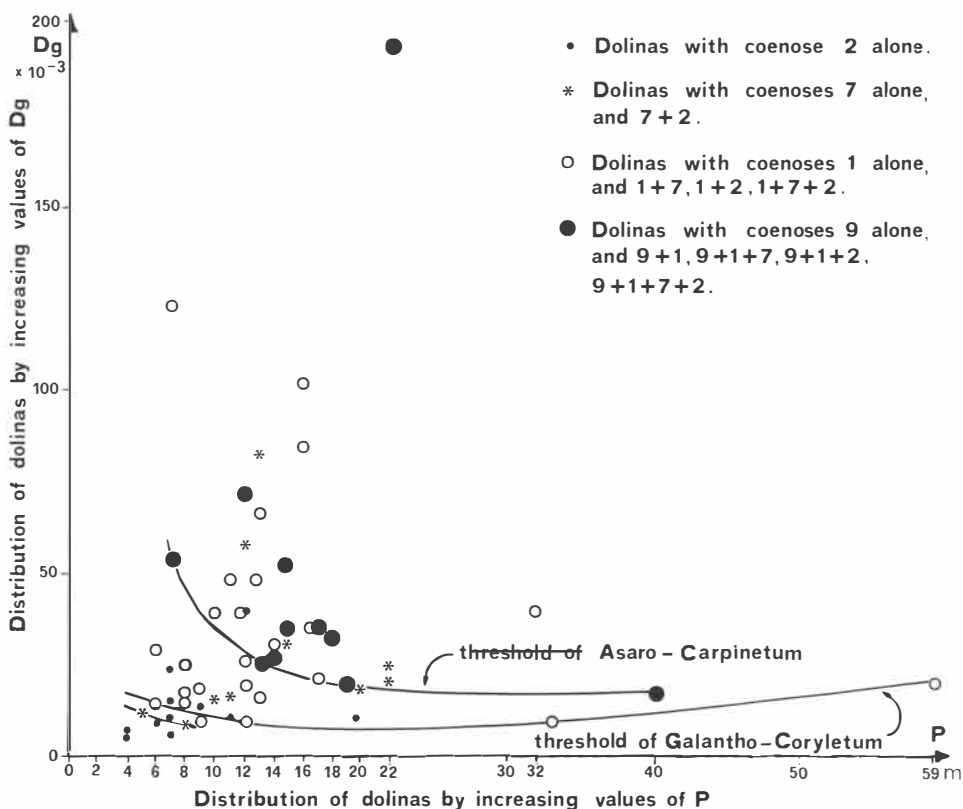


Fig. 2 — Threshold of presence of primary coenoses in dolinas.

corresponds to depth class *P3*.

An important ecological deduction may be made about the A-C from the above observations: the presence of this coenose in the dolinas studied is not determined by their depth alone, but by the relationship between their depth and width of mouth.

It should also be noted that this coenose is of maximum frequency in the class of minimum potential *U1*. It may be presumed that pedological factors and other conditions favourable to this coenose have also discouraged the exploitation of this environment.

While the A-C has a precise threshold line, that of G-C is not clearly discernable, and the threshold of S-Q is practically non-existent. The A-C dolinas have the role of working against anthropization and floristic alteration. The connection between European, Euro-Asiatic and Euro-Siberian geophytes, typical of coenoses A-C, and its low level of anthropization has been demonstrated (Poldini and Vidali, in press); this in turn is connected to the minimum level of potential of these dolinas.

Bearing in mind that geomorphological discontinuity (function *Dg*) has a selective function as far as external primary coenoses are concerned, and that O-Q is present in the dolinas as a result of penetration from the outside, increasing levels of vegetational diversity (*Dv*) may be identified by means of an analysis of the presence of primary coenoses in the dolinas.

The ascending order of vegetational diversity, divided into four levels, is given by:

- Low *Dv* in dolinas with O-Q alone
- Medium-low *Dv* in dolinas with O-Q and S-Q
- Medium-high *Dv* in dolinas with O-Q, S-Q and G-C
- High *Dv* with O-Q, S-Q, G-C and A-C

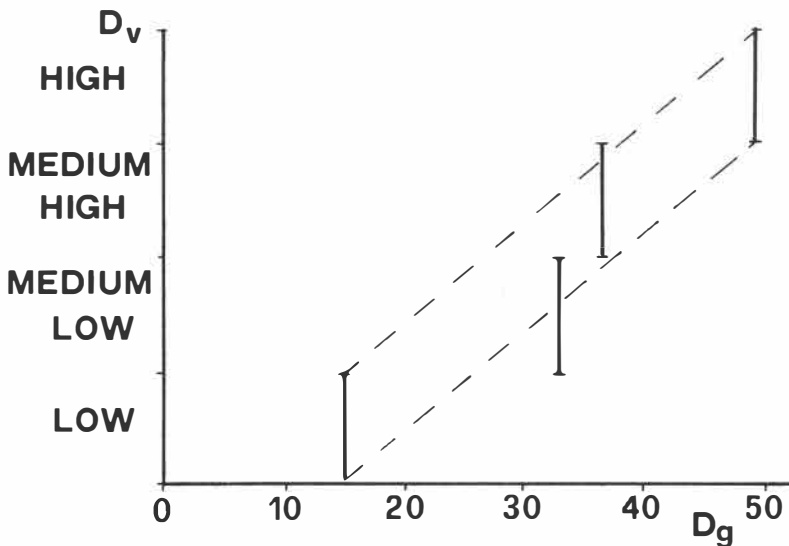


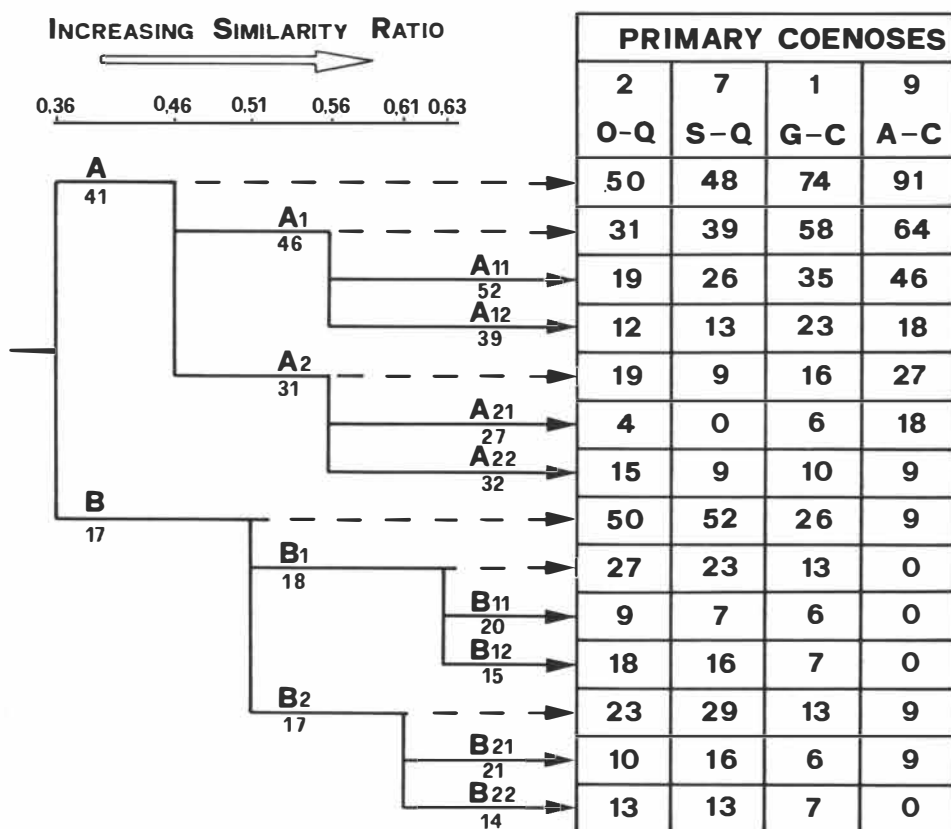
Fig. 3

The dependence of the vegetational diversity D_v upon geomorphological discontinuity D_g may thus be expressed in the Figure 3.

The D_g axis shows the average D_g values for the groups of dolinas belonging to the four D_v levels. The dependence of D_v on D_g is almost linear - the vegetational diversity increases in a linear way with the growth of geomorphological discontinuity.

3. Conclusions

The study of the similarity between dolinas, based on primary coenoses and geomorphological features, has produced the results shown in the table 7, the interpretation of which, presented in graph form, is confined to the first three levels.



Tab. 7

The table 7 shows, for example, that dolinas containing G-C are shifted by 74% on cluster A with an average D_g of 41 (26% on B, average D_g 17) which is

subsequently shifted to 58% and 16% in A1 and A2 respectively.

The shift of the dolinas on clusters A and B is particularly significant. A contains dolinas of a high level of geomorphological discontinuity (41) with maximum frequency of G-C and A-C (74% and 91% respectively). The presence of oak coenoses is less marked. This group of dolinas, which may be globally defined as the "*Asaro-Carpinetum*" type, represents the continental extreme of the ecological spectrum of the Karst region near Trieste.

This characteristic becomes progressively more accentuated in the subsequent shifts on clusters A1 and A11, with an even higher *Dg* (56 and 52 respectively), medium high rockiness and medium low potential.

Symmetrically, B, B2 and B22 contain a concentration of dolinas of low *Dg*, with minimum values for A-C and G-C and with a presence of oak dolinas equal to that of line A, A1 and A11. The morphological characteristics of these groups are low rockiness and medium high potential. It may therefore be concluded that, above a common base presence of oak dolinas in clusters A and B, the continental component A-C and G-C is added to cluster A alone.

The above considerations lead to the following classification:

I O-Q dolinas

II S-Q dolinas

III A-C dolinas

It should be pointed out that this classification is not "exclusive" but "cumulative" in that the group of "A-C dolinas" includes the sub-group of "S-Q dolinas" which includes "O-Q dolinas".

Riassunto.

Le relazioni tra vegetazione e geomorfologia delle doline nel Carso triestino sono descritte sulle basi di un modello ecologico. Vengono riportate osservazioni sulla classificazione delle doline in base alla loro vegetazione.

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Authors' addresses
Prof. L. Poldini
Dipartimento di Biologia
Cas. Università
I-34100 Trieste
Dr. D. Favretto
via dei Moreri
I-34100 Trieste

**EVIDENCE FOR THE EXISTENCE AND SPATIAL DISTRIBUTION OF A
CHEMICAL VARIABILITY IN *HELLEBORUS MULTIFIDUS* VIS.
subsp. *ISTRIACUS* (SCHIFFNER) MERXM. & POD. IN THE
NORTH-ADRIATIC KARST REGION**

Laura COASSINI LOKAR, Livio POLDINI *

Keywords: *Helleborus multifidus* subsp. *istriacus*, *Ranunculaceae*, chemical variability, spatial distribution, ecological adaptation.

Abstract. *Helleborus multifidus* subsp. *istriacus* is an endemic Illyric Dalmatian species, that in the north-Adriatic area occurs at the border between Italy and Yugoslavia. The entity produces two bufadienolides (hellebrin and glucohellebrin) in the hypogeal organs. Three types of population are identified on the basis of their quantitative variations and their distributive ratio between roots and rhizomes. Their ranges have been established on a 140 Km² area near Trieste (Friuli-Venezia Giulia). This distribution patterns seem to be related with a gradient in water availability. The correlation between phytochemical variability and variation of climatic factors, suggest that the investigated substances could have an adaptative value in respect with the ecology of the *Helleborus* entity.

Introduction

The present paper examines the distribution of chemical types of *Helleborus multifidus* subsp. *istriacus* in a part of the Karst area along the coast of the north-eastern Adriatic sea. This area is the north-easternmost section of the Dinaric system. Precipitations ranges from 1000 mm/year on the coast to 1400 mm/year on the first mountains in the northernmost part, while in the east it reaches an average of 1600 mm/year. Illyrian species characterize the flora; they have often given origin to neo-endemic forms (Poldini, 1978).

According to Merxmüller and Podlech work's (1961) the group of studied plants is ascribed to *Helleborus multifidus* Vis. subsp. *istriacus* (Schiffner) Merxm. & Pod.. However, previous authors (Hegi, 1906; Fiori, 1923-1925; Schiffner, 1890) classify the taxon as subordinate to *Helleborus odoratus*, present in the south-eastern Alps; our personal data (unpublished) reach the same conclusion. Without discussing so far here the systematic position of the entity we will call it *H. istriacus* in the present work.

H. istriacus prefer calcareous soils and is bound to the cooler types of the thermophytic woods. It figures among several phytosociological groups in the north Adriatic Karst region. In the part of the studied territory it is found in two associations: one situated at heights lower than 300 m, the other located above 400

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m and in the transitional region between these two association areas (between 300 and 400 m). This relatively wide distribution implies probably a genetic diversity giving it such a plasticity. Very few studies have been done at an infraspecific level on the chemical variability of plant populations (Vernet et al., 1977a; 1977b; Lincoln et al., 1976; 1978; Geshenzon, 1978); nevertheless the study of thyme suggests that genetic diversity of oil polymorphism and wide ecological distribution are correlated.

If many works have been carried out on the genus *Helleborus* L. (Wissner & Kating, 1971, 1974a, 1974b, 1974c; Petričić et al., 1967, 1971; Hardman & Benjamin, 1976, 1980) very little is known from a chemical point of view. A "in toto" analysis of the hypogean organs (Wissner & Kating, 1971, 1974a, 1974b, 1974c; Cioaca & Cucu, 1974; Vennes, 1977; Petričić et al., 1977; Kritikos & Philianos, 1963, 1969; Hardman & Benjamin, 1980) has showed the presence of secondary compounds in such organs, especially two bufadienolides: hellebrin and glucohellebrin. But, nothing is known about an infraspecific variability. Do chemical types occur in *H. istriacus* and, if any, what is their spatial distribution?

Materials and methods

Plant material and sampling

We have examined a territory of 140 Km² located on the Trieste Karst (fig. 1). This territory is characterized by a uniform geological substratum (limestone). The area has been subdivided into a grid of 35 units (each of 4 Km²). They are distributed in the following way: 16 units in the area of the association *Carici-Centaureetum rupestris* (Area A), 10 units in the area with a vegetation belonging to the association *Chrysopogono-Centaureetum cristatae* (Area C), and 9 in the transitional area (Transitional Karst) (Area B) (v. fig. 1).

The 35 units of the grid are distributed along an elevation gradient (from the maximum altitude of 670 m at ESE to the minimum altitude of 250 m at WNW). This gradient corresponds to a gradient of increasing dryness, which can be identified on the basis of two entities: *Satureja montana* L. subsp. *variegata* (Host) P.W. Ball and *Satureja subspicata* Bartl. ex Vis. subsp. *liburnica* Silić. The first indicates drier conditions than the second (Poldini, in press).

The number of units of the grid decrease from south-east to north-west, as the numerical consistency of the entity *H. istriacus* becomes rarefied from east to west, where the north-western limit of its distribution lies.

Two sets of samples were collected in every unit of the grid:

a) samples of 15 individuals of the same age for immediate chemical analysis (3 year) (Coassini Lokar et al., 1982b, 1983), in the same phase of the biological cycle (maximum leaf development) (Coassini Lokar et al., 1982b, 1983), at random for three years consecutively;

b) samples of 15 individuals (about one year old) were collected to test stability of chemical characters after transplantation. They were transplanted and cultivated for three consecutive years in the greenhouses of the Botanical Garden of Trieste University. After this period all the individuals, grouped according to the three

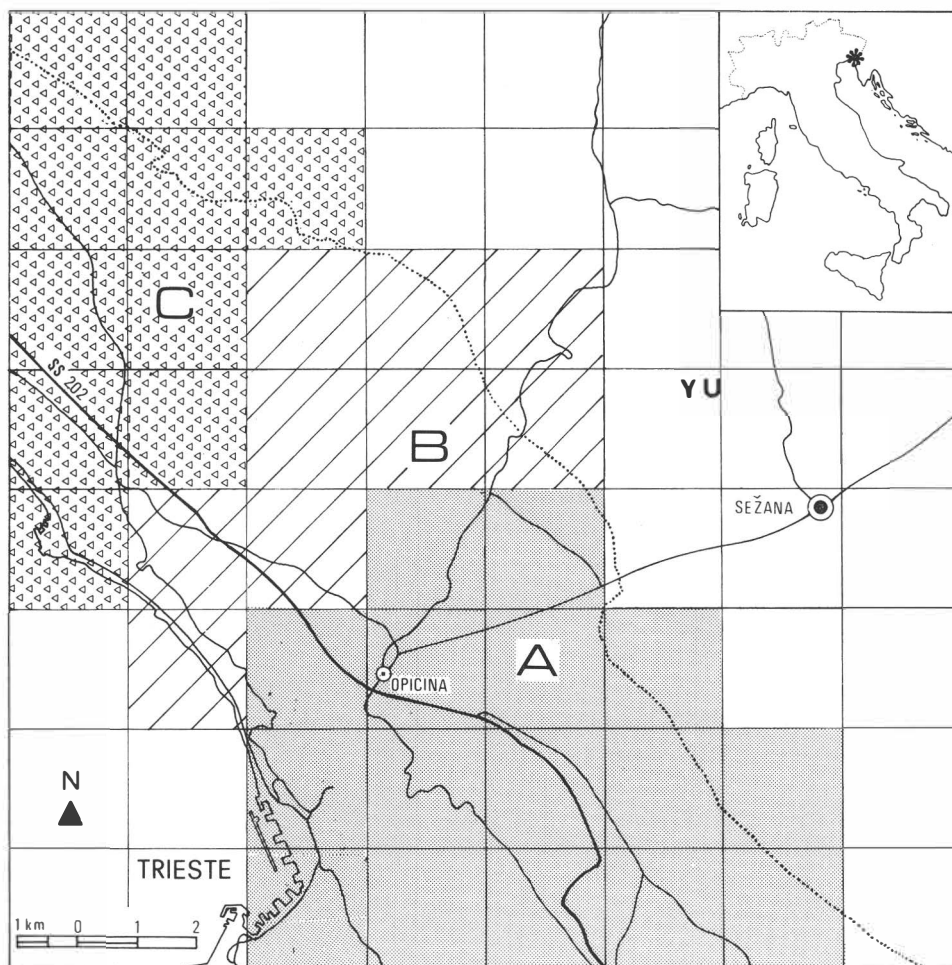


Fig. 1 — Map of distribution of the 35 units of the grid in the Karst area (A = sub-montane Karst above 400 m; B = transitional area between 300 and 400 m; C = hilly Karst inferior to 300 m). Area sampled for intraspecific variability of *H. istriacus*.

areas of origin (A, B, C) were collected at the phase of maximum leaf-expansion; hypogean organs were analyzed, rhizomes and roots separately.

Methods of chemical analysis

The different underground parts of fresh plants were washed and air dried. The powdered (60 mesh) roots and rhizomes (1 g) were Soxhlet extracted first with petroleum ether (30-40°, 4 hrs) and then exhausted with MeOH (4 hrs). The MeOH extract was concentrated in a rotavapor and the residue dissolved in absolute methanol in a tared flask (10 ml). TLC methods are conveniently applicable to the

separation and detection of bufadienolides in plant extracts. Development with CHCl_3 : CH_3OH : H_2O = 4 : 1 : 0.2 (v/v); 100 μl of the methanolic extract applied in bands (quantitative determination). Spots or bands were detected by UV fluorescence with a UV-254 light. Samples of the pure compounds (authentic markers) prepared by Hoffmann La Roche, Basel, Suisse. Lowest limit of detection was 2.5 μg . The authentic markers and the compounds isolated from *H. istriacus* populations were identified and characterized as such by their chromatographic behaviour (R_f) in a series of TLC systems, colour reaction with p-dimethylaminobenzaldehyd, UV-visible data, m.p., elemental analysis (Coassini Lokar et al., 1983). Silica gel of bands area was scratched (purity of the sample thus obtained was at least 97%), eluted with spectral methanol, centrifugated (6000 r/min for 10'), treated with the specific reagent (4 ml), carried in tared flask (5 ml). After 1^h 30' the reaction was completed. The visible spectra were measured on a Perkin Elmer spectrophotometer with a data integrator. In hellebrin's visible spectrum there are three bands of absorption at $\lambda_{\text{max}}^{\text{MeOH}} = 500 \text{ nm}$ ($\epsilon = 1.449 \pm 0.05 \times 10^4$), 400 nm, 540 nm (shoulder). In glucohellebrin's visible spectrum there are two bands of absorption at $\lambda_{\text{max}}^{\text{MeOH}} = 498 \text{ nm}$ ($\epsilon = 1.435 \pm 0.1 \times 10^4$), 540 nm (shoulder). ϵ obtained by least squares from 13 observations in the concentrations range 0.0100-0.0600 mg/ml. The sensibility for 0.0125 mg/ml was $\sigma_{n-1} = 0.30577$, $\sigma_n = 0.24966$. The content of bufadienolides determined in the different parts of fresh plants was calculated as percent of dry-weight (mean of three separated analysis). The Tables reported in text refer to average of samples collected in various grid's units in the course of three years. The variation from year to year is within $\pm 1.2\%$ for hellebrin and within $\pm 1.4\%$ for glucohellebrin, for a content of 1.0%.

Methods of data analysis

The analyzed samples have been grouped in to three classes according to the three areas (A, B, C) in which they have been collected. The three classes have been compared by stepwise multiple discriminat analysis (program discriminant of the SPSS package; Nie et al., 1975), using the data from the chemical analysis of hellebrin and glucohellebrin. Average values of 16 populations from the area A, 10 populations from the area C, and 9 populations from the area B have been used.

Analysis of the results

a) Analysis on the wild populations.

The analyses which were separately performed on roots and rhizomes of *H. istriacus*, gave the following results:

- hellebrin (cardiotonic diglycoside) and glucohellebrin (cardiotonic triglycoside) were present in all the samples which derived from the 35 units of the grid;
- hellebrin is always in greater quantities in the roots, while glucohellebrin is in greater quantities in rhizomes, regardless of the place of origin of the sample;
- hellebrin is the bufadienolide always present in higher quantities.

The average percentage value in the hypogeal organs "in toto" in the 35 units of the grid is 0.87. The same value for glucohellebrin is 0.33;

Table 1

Samples	roots (V ₁)	hellebrin % in rhizomes (V ₂)	ratio (V ₃)	roots (V ₁)	glucohellebrin % in rhizomes (V ₂)	ratio (V ₃)	hellebrin + glucohellebrin % in hypogaeal part "in toto"
	E ₁	E ₂	E ₁ /E ₂	G ₁	G ₂	G ₁ /G ₂	
A	1	1.040	0.608	1.711	0.391	0.434	0.900
	2	1.382	0.790	1.750	0.312	0.346	0.900
	3	1.335	0.769	1.736	0.598	0.665	0.900
	4	0.434	0.252	1.720	0.194	0.215	0.900
	5	0.575	0.328	1.752	0.246	0.269	0.916
	6	0.472	0.276	1.711	0.200	0.222	0.900
	7	0.940	0.533	1.766	0.310	0.341	0.909
	8	0.793	0.457	1.734	0.376	0.412	0.913
	9	0.729	0.422	1.728	0.262	0.285	0.920
	10	1.425	0.807	1.767	0.330	0.367	0.900
	11	0.614	0.349	1.787	0.290	0.322	0.900
	12	0.851	0.497	1.713	0.346	0.385	0.900
	13	0.755	0.425	1.776	0.363	0.403	0.900
	14	0.581	0.336	1.728	0.153	0.166	0.917
	15	0.648	0.375	1.729	0.196	0.218	0.900
	16	0.667	0.389	1.713	0.242	0.268	0.900
A	0.828 ± 0.18	0.476 ± 0.25	1.738 ± 0.020	0.300 ± 0.12	0.332 ± 0.25	0.905 ± 0.07	0.969
B	1	1.017	0.500	2.034	0.275	0.375	0.733
	2	1.001	0.497	2.014	0.284	0.382	0.744
	3	1.163	0.582	2.000	0.344	0.466	0.740
	4	1.057	0.528	2.000	0.208	0.276	0.752
	5	1.233	0.611	2.000	1.190	0.230	0.739
	6	1.115	0.545	2.049	0.184	0.251	0.732
	7	1.420	2.000	0.289	0.388	0.746	1.742
	8	1.299	0.643	2.020	0.250	0.338	0.740
	9	1.272	0.614	2.071	0.351	0.470	0.747
B	1.174 ± 0.07	0.581 ± 0.11	2.021 ± 0.030	0.260 ± 0.09	0.353 ± 0.075	0.741 ± 0.007	1.223
C	1	1.668	0.402	4.151	0.234	0.414	0.565
	2	1.554	0.378	4.116	0.214	0.377	0.569
	3	1.649	0.399	4.128	0.231	0.408	0.565
	4	2.559	0.614	4.167	0.309	0.604	0.512
	5	1.762	0.429	4.110	0.238	0.420	0.567
	6	1.714	0.417	4.109	0.205	0.351	0.585
	7	1.747	0.420	4.159	0.212	0.370	0.573
	8	1.296	0.316	4.108	0.247	0.424	0.583
	9	1.802	0.439	4.107	0.280	0.485	0.577
	10	1.554	0.374	4.151	0.217	0.372	0.585
C	1.731 ± 0.08	0.419 ± 0.20	4.131 ± 0.020	0.220 ± 0.07	0.385 ± 0.05	0.568 ± 0.024	1.405

A, B and C mean value of **A**, **B** and **C** populations and standard error.

Tab. 1 — Percentage of hellebrin and glucohellebrin in rhizomes (V₁) and roots (V₂), ratio roots/rhizomes values (Id = V₃), hellebrin + glucohellebrin content in hypogaeal parts "in toto".

Table 2

Sampling areas	populations/ grid's units	$\bar{\text{Id}}_E$	$\pm \sigma_{n-1}$	$\pm \sigma_{n-1} \%$	$\bar{\text{Id}}_G$	$\pm \sigma_{n-1}$	$\pm \sigma_{n-1} \%$
A	1-16	1.7390	0.0247	1.42	0.9050	0.0075	0.83
B	1- 9	2.0210	0.0254	1.25	0.7410	0.0066	0.89
C	1-10	4.1310	0.0239	0.58	0.5680	0.0239	3.75

Tab. 2 — Distribution ratio of hellebrin (Id_E) and glucohellebrin (Id_G) between roots and rhizomes of the populations of *H. istriacus* from the three sampling areas (A, B, C) with standard errors.

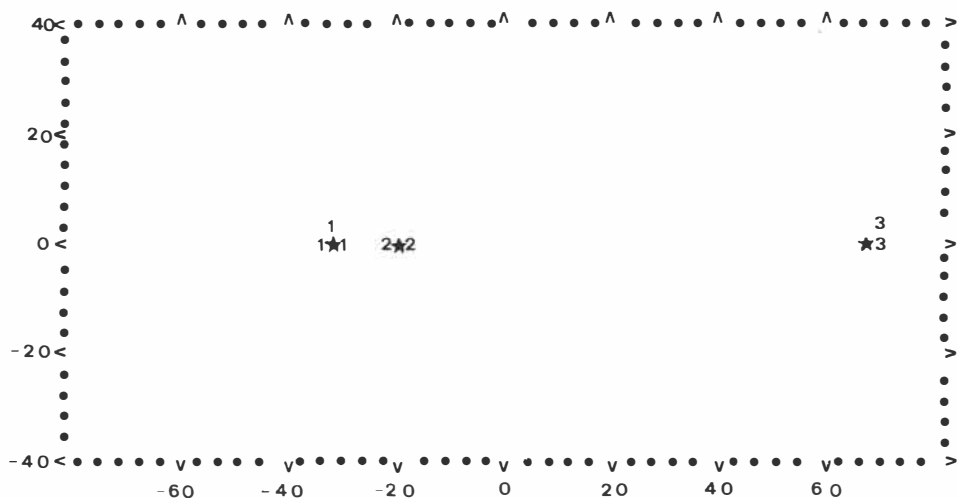


Fig. 2 — Ordination of the three populations of *H. istriacus* according to the first two canonical varieties of discriminant analysis, based on hellebrin data.

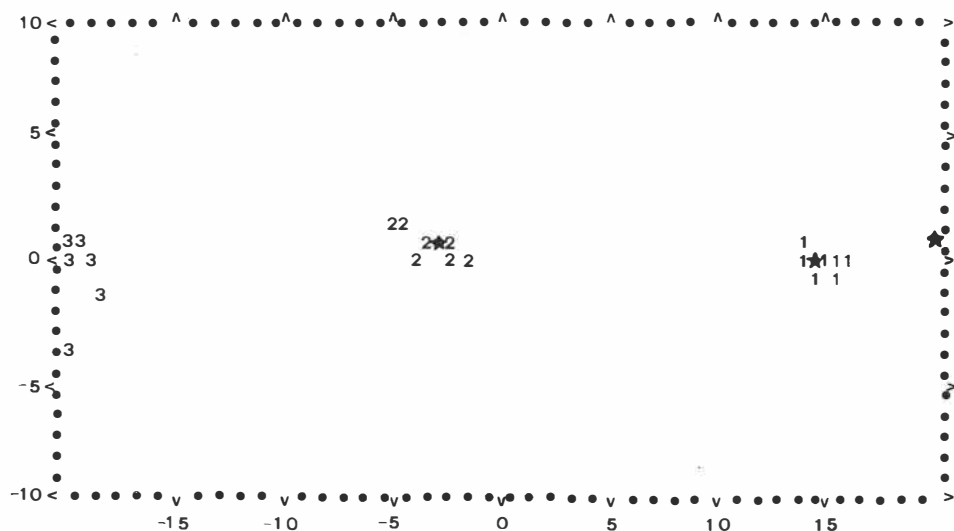
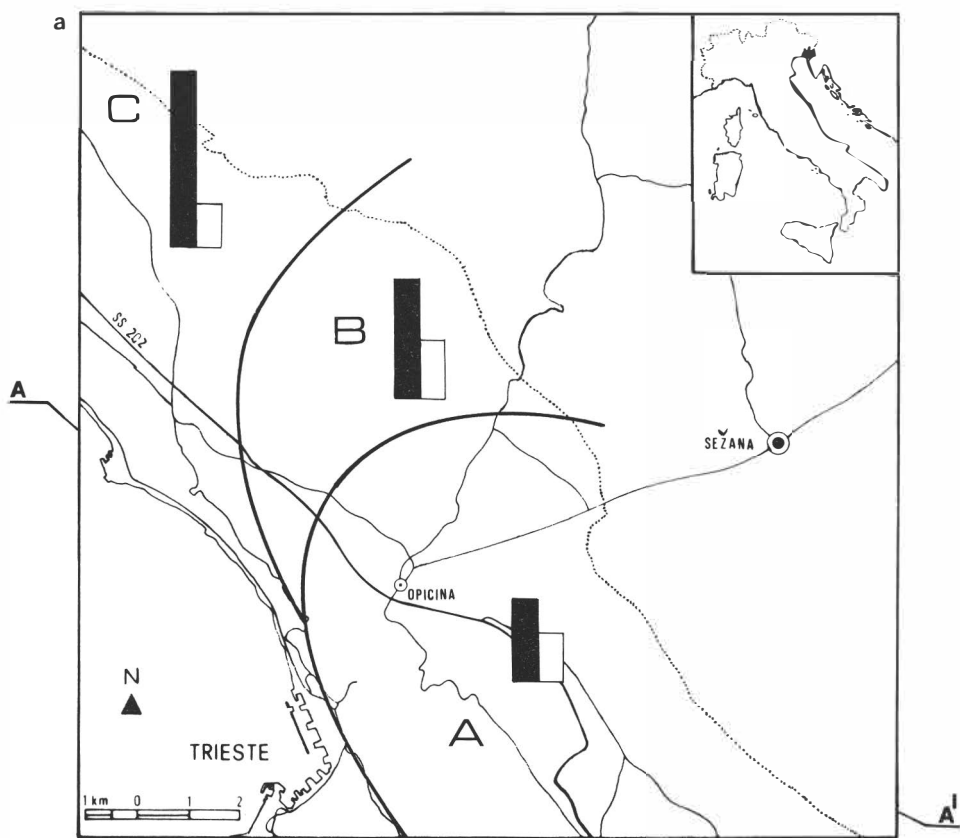


Fig. 3 — Ordination of the three populations of *H. istriacus* according to the first two canonical varieties of discriminant analysis, based on glucohellebrin data.

- the hellebrin content increases in the roots with increasing dryness; in the 16 populations of the area A the average content in the roots is 0.83, in the 9 populations of the area B is 1.17 and finally in the 10 populations of the area C is 1.73;

- in the hypogeal organs "in toto" the average values are respectively 0.65 (A),



b sect. A-A'

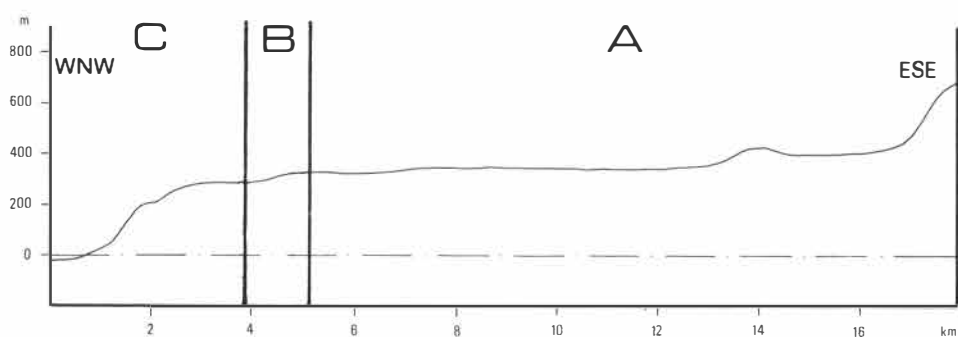


Fig. 4 — a. Distribution of the three chemical types of *H. istriacus* in the studied area. A = area of *Carici-Centaureetum rupestris* with *Satureja subspicata* subsp. *liburnica*; B = transitional area; C = area of *Chrysopogono-Centaureetum cristatae* with *Satureja montana* subsp. *variegata*.

Histograms represent the ratio of hellebrin content in roots (black) and rhizomes (white).
b. Profile of the area along the transect AA'.

0.88 (B), 1.08 (C);

- the total content of the two bufadienolides (hellebrin + glucohellebrin) increases from East to West, and is related with the three areas above considered: $0.97 \rightarrow 1.22 \rightarrow 1.41\%$ (A $\rightarrow$ B $\rightarrow$ C);

- the glucohellebrin increases constantly in the rhizomes ($0.33 \rightarrow 0.34 \rightarrow 0.39\%$) and proportionally decreases in the roots ($0.30 \rightarrow 0.26 \rightarrow 0.22$) with the gradient of increasing dryness;

- the ratios between the percentage content of hellebrin and glucohellebrin in roots and in rhizomes are constant for the populations of the three sampling areas (A, B, C). This distribution ratio has been marked as Id . Id_E is the distribution ratio of hellebrin between roots and rhizomes and Id_G is the distribution ratio of glucohellebrin.

The results are summarized in the Table 1 and 2.

- On the basis of hellebrin data, the discriminant scores were for area A = -31.6125 , for B = -20.0522 , for C = $+68.7452$. On the basis of glucohellebrin data, the average discriminant scores were for area A = $+14.39444$, for area B = -3.15378 , for C = -20.2559 . The attribution of the samples of *H. istriacus* to the three different types is therefore highly significant (fig. 2, 3).

- The analysis of the simple variation between the three populations shows that all the parameters taken into consideration for hellebrin are highly significant ($V_1 = .0001$, $V_2 = .0409$, $V_3 = .0000$; see Table 1). For glucohellebrin the only significant parameter is V_3 ($V_1 = .8511$, $V_2 = .0957$, $V_3 = .0000$).

- The parameter $Id (= V_3)$ assumes a grater meaning in the case of hellebrin ($F = 2170,2910$) than of glucohellebrin ($F = 31221,2006$).

- Therefore we have identified three chemical types of *H. istriacus*, which differ for the quantity of bufadienolides in the hypogaeal organs and for their distribution pattern between roots and rhizomes. Their distributions coincide with areas of the two plant associations (respectively *Carici-Centaureetum rupestris* and *Chrysopogono-Centaureetum cristatae*) and with the transitional area (fig. 4).

b) *Samples studied after three year cultivation in an experimental garden:*

- the analyses performed on the samples transplanted and cultivated, grouped according to the three areas of origin (A, B, C), show that the values of Id_E and Id_G remain constant and identical to the values determined for the "spontaneous" samples. The samples which were cultivated have a slightly lower content of bufadienolides than "spontaneous" ones (Tab. 3).

Conclusions

The phytochemical investigations performed on *H. istriacus* allowed to study the relationship between the ecological adaptability of this entity and its distribution in the north-Adriatic Karst territory.

As there are no meteorological data on the area from south-east to north-west, the variation of vegetation from the submontane to the colline Karst has been considered as an indirect measurement of the total climatic variations.

By subjecting the quantitative data of the two bufadienolides present in the

Table 3

Samples	HELLEBRIN ($\bar{x}\%$)					
	in "spontaneous" samples			in cultivated samples		
	roots E_1	rhizomes E_2	ratio Id E_1/E_2	roots E_1	rhizomes E_2	ratio Id E_1/E_2
A	0.830	0.476	1.741	0.798	0.458	1.741
B	1.174	0.581	2.021	1.119	0.554	2.021
C	1.731	0.419	4.132	1.700	0.410	4.139

	GLUCOHELLEBRIN ($\bar{x}\%$)					
	roots G_1	rhizomes G_2	ratio Id G_1/G_2	roots G_1	rhizomes G_2	ratio Id G_1/G_2
A	0.301	0.332	0.904	0.292	0.321	0.910
B	0.262	0.353	0.742	0.250	0.341	0.734
C	0.220	0.385	0.570	0.209	0.371	0.562

Tab. 3 — Comparison between hellebrin and glucohellebrin contents ($\bar{x}\%$) in the "spontaneous" and cultivated samples of *H. istriacus* from the three zones.

single hypogeal organs to discriminant analysis, it has been possible not only identify three chemical types of populations of *H. istriacus* but also establish their spatial distribution. The chemical type of *H. istriacus* with lower content of bufadienolides occurs in vegetation of association *Carici-Centaureetum rupestris* (area A).

The chemical type with greater amounts of the two bufadienolides is within the association *Chrysopogono-Centaureetum cristatae* (area C). In the transitional area B there is a chemical type with an intermediate content of bufadienolides. Populations coming from these three zones are clearly strongly different, especially concerning root/rhizome ratio. Since there is a gradient of increasing dryness from the association *Carici-Centaureetum rupestris* to the association *Chrysopogono-Centaureetum cristatae*, it seems that the production of cardioactive glycosides can be correlated to the degree of dryness of the environment.

A high correlation exist therefore between chemical type of populations and environment, characterized both by altitudinal position and species associations. The real factor influencing this distribution, acting directly or indirectly, could be the dryness of the soil.

The persistence of the differences between populations after transplant experiment in a same environment demonstrates genetic differences between them.

A preliminary study at individual level has demonstrated that all individuals present in each area have the same root/rhizome ratio. The chemical types are therefore probably chemical varieties.

The hellebrin ratio does not vary according to climatic environmental factors or

to the degree of ripeness; it appears genetically determined and submitted to individual selection, a point that should be further studied. Moreover, the studies so far performed suggest a possible ecophysiological role for hellebrin and glucohellebrin in *H. istriacus*.

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Riassunto.

Helleborus multifidus subsp. *istriacus* è una specie endemica illirico-dalmatica, che nell'area nord-adriatica si colloca ai confini tra l'Italia e la Jugoslavia. L'entità produce due bufadienolidi (ellebrina e glucohellebrina) negli organi ipogei. Sono stati identificati tre tipi di popolazioni sulla base delle variazioni quantitative di tali composti e sulla base del loro rapporto di distribuzione tra radici e rizoma. È stata stabilita la loro distribuzione in un'area di 140 Km², nelle vicinanze di Trieste (Friuli-Venezia Giulia).

Tale distribuzione sembra essere correlata con un gradiente di aridità. L'evidente correlazione tra variabilità fitochimica e fattori ambientali suggerisce che le sostanze investigate possono avere un valore adattativo nei confronti dell'ecologia dell'entità studiata.

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Authors' address
 Prof. Dr. L. Poldini
 Prof. Dr. L. Coassini-Lokar

Department of Biology, University of Trieste, Via Valerio, 30, I-30100 Trieste

L'ASARO-CARPINETUM BETULI Lausi 64 DEL CARSO NORDADRIATICO

Livio POLDINI*

Keywords: North Adriatic Karst, Trieste, *Carpinus betulus* wood of dolinas.

Abstract: This paper describes in a more detailed way the *Carpinus betulus* wood - previously typified by its Author by means of a synthetic table - which grows on the north-oriented slopes of dolinas (sinkholes) and gives its subdivision in subassociations.

1. Scopo della presente nota

La vegetazione forestale che ricopre i versanti volti a nord delle doline del Carso triestino è stata descritta per la prima volta con il nome di *Asaro-Carpinetum betuli* Lausi 64 (AC). L'A. riportava con tabella sintetica il tipo che, risalendo a data anteriore al 1979, risulta validamente pubblicato.

Da allora la comparsa di numerose tabelle sintetiche riguardanti cenosi a carpino bianco dominante, dislocate a sud delle Alpi (Oberdorfer e Hofmann, 1967; Horvat et al., 1974; Marinček, 1979) e la ridefinizione del *Carpinion illyricum* unitamente alla descrizione dei carpineti submediterranei in Slovenia e nel Friuli-Venezia Giulia (Marinček et al., 1983), ci inducono a render noti rilievi effettuati in questi anni che ci consentono una migliore definizione dell'AC nell'ambito dell'alleanza illirica e la sua articolazione in subassociazioni.

2. Caratterizzazione della cenosi

L'appartenenza dell'AC al *Carpinion illyricum* (Horvat) Marinček et al., 83 è assicurata da *Primula vulgaris*, *Galanthus nivalis*, *Crocus napolitanus*, *Erythronium dens-canis*, *Lonicera caprifolium*. A questo gruppo di specie che caratterizzano l'alleanza dal lato corologico sono stati assimilati gli elementi del *Carpinion betuli* centroeuropeo *Carpinus betulus*, *Lathraea squamaria*, *Prunus avium*, *Crataegus laevigata*, ai quali va aggiunta *Carex pilosa*, che nella tabella appare fra le diff. di subass.

L'AC non possiede proprie specie caratteristiche. In senso generale e cioè nei confronti di tutte le associazioni del *Carpinion illyricum* fin qui note essa si differenzia per la presenza di *Isopyrum thalictroides* (IV), *Mercurialis ovata* (III) e *Scilla bifolia* (III). Localmente e cioè nell'ambito del Carso litoraneo ove avviene la

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Asaro - Carpinetum Lausi 64

Numero rilievi		11111111	12345678901234567		
Altezza s.l.m. (x10 m)		1121131112234243	70678748889054302		
Inclinazione		122 1 211 2322	555 0 50050555		
Esposizione		NN NN	NNN N EENNNNNNNN	Presenza	Frequenza
Numero specie		33433224444332221	45079985208165336		
D Isopyrum thalictroides (Cl)		121+ 11+3 + 11	11 4		
Mercurialis ovata (Cl)		+++ ++++ 1 +	9 3		
Scilla bifolia		+ +11 +++	7 3		
d1 Asparagus tenuifolius		+++	3 1		
Lathyrus niger		+ +	2 1		
Polygonatum odoratum		++	2 1		
Buglossoides purpureocaerulea		+	1 1		
d2 Ranunculus ficaria ssp.bulbifer		1+4	3 1		
Gagea lutea		+1+	3 1		
d3 Carex pilosa (All)		1313	4 2		
Majanthemum bifolium		2++	3 1		
d4 Dentaria enneaphyllos		3332	4 2		
Actaea spicata		2++	3 1		
Geranium robertianum		1 +2	3 1		
Asplenium trichomanes		+ +1	3 1		
A11 Carpinus betulus	A1	22 222 34 312			
	A2	2323224432224 3			
	C	313321 21222 22	16 5		
Primula vulgaris		111+1+111+11 +1	14 5		
Galanthus nivalis		+1211 1311222	12 4		
Crocus napolitanus		2 33 112 2	7 3		
Erythronium dens-canis		11211 +1	7 3		
Lathraea squamaria (loc.)		+++++ +	6 2		
Prunus avium	A1	1 1 1 1			
	C	++	6 2		
Crataegus laevigata		1+ 1	3 1		
Stellaria holostea		1 2	2 1		

			1	1	1
0	Lonicera caprifolium		+1221+122+112+2	1	16
	Asarum europaeum		2 +++21+1111	1 +	13
	Carex digitata		1+1++ + ++1	1 ++1	13
	Lathyrus vernus		+++ 11++++11	+	12
	Symphytum tuberosum		+ 12+12	1+21211	13
	Lamium orvala		1+11+ + +	+1 + +	11
	Viola reichembachiana		++1 + 1+ 1+	1 +	10
	Cyclamen purpurascens		+1	1 1++	11
	Polygonatum multiflorum		++11 1 1	1 1	8
	Salvia glutinosa		++	++++1	7
	Anemone ranunculoides		+	1+1+ +	6
	Galium laevigatum		+	1+r1 +	6
	Pulmonaria officinalis			221 211	6
	Hacquetia epipactis		11	11 12	6
	Corydalis cava			11+ 1 +	5
	Euphorbia dulcis			11+ 1+	5
	Melica nutans			++ + ++	5
	Campanula trachelium		+	+	1+
	Brachypodium sylvaticum		1 ++	1	4
	Mercurialis perennis			3 2 2+	4
	Lamiastrum montanum		+	+1	+
	Sanicula europaea			1	+1
	Acer pseudoplatanus	A2			3
	Corydalis solida			1 1+	3
	Dryopteris filix-mas			+	1
	Tilia platyphyllos	A1		1	
		C	1		2
	Acer platanoides	A2	2		1
	Aremonia agrimonioides		r		1
	Paris quadrifolia		+		1
	Cardamine bulbifera		+		1
C1	Corylus avellana		122111	123232212	15
	Anemone nemorosa		1+112211	1311++	14
	Acer campestre	A2	212 11	11 1 12	12
		C	221	2	2
	Sesleria autumnalis		++1+	1 111 + 1+	11
	Euonymus europaea		++1+11	11 + +	10
	Helleborus istriacus		+2 ++	11 22 + +	10
	Hedera helix		21 +1 +	1+ 221	10
	Hepatica nobilis			11+ 1++ 11++	10
	Quercus cerris	A1	12 31	2 122	8
	Festuca heterophylla		1++++	211	8
	Cornus mas		12+	211	1
	Fraxinus ornus	A2	+	++	21
		C	1	1	7
	Lathyrus venetus		+	++ 1 +1	6
	Crataegus monogyna		+	+11 2 1	6
	Convallaria majalis		++	+11 1	6
	Euonymus verrucosus		1	++ 1 1	5
	Viola riviniana		++	+	1

Tilia cordata	A1	2							
	A2	1		1	2		4	2	
Ostrya carpinifolia	A1				1				
	A2	1			3				
	C				21		4	2	
Melittis melissophyllum		++	1		+		4	2	
Sorbus torminalis	A2	1							
	C	1	1				3	1	
Cornus sanguinea		1+	1				3	1	
Adoxa moschatellina			+1		+		3	1	
Knautia drymeia ssp. tergestina		+	+				2	1	
Campanula persicifolia		+		1			2	1	
Viola mirabilis			+	1			2	1	
Prunus spinosa		+					1	1	
Clematis vitalba		+					1	1	
Acer monspessulanum		1					1	1	
Ligustrum vulgare				1			1	1	
Berberis vulgaris					1		1	1	
Lonicera xylosteum					1		1	1	
Carex sylvatica		1					1	1	
Tanacetum corymbosum					+		1	1	
Neottia nidus-avis					+		1	1	
C Quercus petraea	A1	112122	22232	1					
	A2	1 1 2	21	1		13	4		
Robinia pseudacacia	A1	11	22						
	A2	21	11 1			9	3		
Heracleum sphondylium			+	+++++		7	3		
Sambucus nigra		1	1	++1	1	6	2		
Glechoma hederacea		+ 2	1+	1+		6	2		
Aegopodium podagraria		+		+11++		6	2		
Serratula tinctoria		+1	++	+		5	2		
Solidago virgaurea				++ + +	+	5	2		
Moehringia trinervia		+	r	+	+	+	5	2	

Lista delle località (*Asaro-Carpinetum*):

1.: Dolina d'Aurisina (I); 2.: Aurisina Velika Njva (I); 3.: Dolina strada per Bristie (I); 4.: Percedol su fondo pianeggiante (I); 5.: Volčigrad pianeggiante (YU); 6.: Volčigrad su fondo piano di dolina (YU); 7.: Divača dolina Risnik (YU); 8.: Pliskovica (YU); 9.: Pliskovica (YU); 10.: Volčigrad (YU); 11.: Dolina Sator presso Štorje (YU); 12.: Coljava-Kosovelo (YU); 13.: dolina Risnik presso Divača (YU); 14.: Alla base settentrionale del Veliki hrib presso Plešivica (YU); 15.: Rocca di Monrupino (I); 16.: Abisso di Ferneti (I); 17.: Grande dolina Borgo Grotta (I).

Lista delle sporadiche (*Asaro-Carpinetum*):

Veronica chamaedrys: + (1), + (10), + (12); Thalictrum aquilegifolium: r (1), + (2), + (8); Carex montana: + (1), 1 (11), + (12); Allium pulchellum: r (1), + (2), + (6); Colchicum autumnale: + (1), + (4), + (12); Ruscus aculeatus: + (2), + (8), + (16); Campanula rapunculoides: + (5), + (11), + (12); Aconitum vulparia: + (7), 2 (11), 2 (13); Castanea sativa: 1 (11), 1 (12); Rubus caesius: + (4), + (16); Geum urbanum: + (1), 1 (4); Ajuga reptans: + (1), + (2); Muscari botryoides: 1 (2), + (5); Dactylis glomerata: 1 (5), + (7); Dactylis aschersoniana: + (8), 1 (9); Mycelis muralis: + (16) + (17); Pinus nigra: 1 (8); Sorbus aria: 1 (16); Ulmus minor: 1 (4); Rosa sp.: 1 (11); Picea abies: 1 (12); Ulmus glabra: 1 (13); Fragaria vesca: + (1); Viola hirta: + (2); Asparagus acutifolius: + (2); Crocus al biflorus: + (4); Stachys sylvatica: + (4); Fragaria moschata: + (4), 1 (8); Circea lutetiana: + (4); Listera ovata: + (4); Viola alba

scotophylla: r (5); Tamus communis: + (8); Cruciata glabra: + (8); Lilium bulbiferum: + (8); Oxalis acetosella: 1 (9); Polypodium vulgare: + (9); Silene cfr. nutans: + (10); Asplenium adiantum-nigrum: + (10); Polytrichum formosum: 2 (10); Hieracum cfr. umbellatum: 1 (10); Smyrnum perfoliatum: r (10); Rumex acetosa: r (12); Ornithogalum pyrenaicum: 1 (12); Senecio nemorus: 1 (13); Veratrum nigrum: 1 (13); Polypodium intermedium: 1 (16); Calamintha nepetoides: + (16); Chelidonium majus: + (16); Viola odorata: + (16); Lamium maculatum: 1 (16); Sedum maximum: + (16); Moehringia muscosa + (16).

sostituzione di *Helleborus odoratus* subsp. *laxus* da parte dell'endemico *H. odoratus* var. *istriacus* (= *H. multifidus* subsp. *istriacus*), concorre alla sua differenziazione uno stuolo di specie provenienti dall'alleanza e dall'ordine essendo questa l'unica associazione dei *Fagetalia* sul pianoro carsico. Si può anzi affermare che l'intera sinusia di geofite efemeroidi primaverili può essere assunta a elemento distintivo fatta eccezione per *Primula vulgaris* e *Lathyrus vernus* che compaiono pure nel seslerio-querceto della rovere. *Isopyrum* è presente pure nello *Staphyleo-Carpinetum* Horvat 63 di Croazia ma con frequenza inferiore (II).

Le specie di ordine sono abbondanti e fra esse *Asarum europaeum* subsp. *caucasicum* p.m.p. è il più costante. Entità del *Fagion illyricum* quali *Cyclamen purpurascens*, *Lamium orvala*, *Hacquetia epipactis* concorrono alla sua differenziazione rispetto i quercu-carpineti transalpini e atlantici.

Fra le specie di classe numerosi gli elementi che provengono dalla formazione boschiva climatogena (*Ostryo-Quercetum pubescentis*) e pertanto illirici e sudesteuropei quali *Sesleria autumnalis*, *Helleborus odoratus* var. *istriacus*, *Quercus cerris*, *Mercurialis ovata* (Diff.). Essi, per effetto di massa, riescono a eludere la selezione operata dall'abbassamento termico.

Fra le compagne l'elemento di maggior rilievo è *Quercus petraea* che concorre unitamente a *Q. cerris* e a *C. betulus* alla formazione dello strato arboreo. Questo si presenta spesso infiltrato da robinia nelle doline di più facile accesso e quindi più antropizzate.

3. Subassociazioni

Non ci soffermeremo sul topoclina di dolina che, come noto, è dominato dall'inversione termica, perché già trattato diffusamente da altri (Polli 1961) e che sta alla base del condizionamento ecologico dell'AC. Qui basti ricordare che l'acidificazione dei suoli, già abbastanza accentuata in tutto il processo pedogenetico carsico per le precipitazioni piuttosto rilevanti, avanza più rapidamente dato lo spessore dei depositi colluviali. Il tipo più diffuso è dato pertanto da suoli bruni subacidi talvolta con manifestazioni evidenti di lisciviazione e idromorfismo.

La dipendenza dell'AC dalle caratteristiche geomorfologiche delle doline vengono descritte in altra sede (Favretto e Poldini, 1986).

Nelle doline meno profonde e ai margini del pianoro carsico in depressa altitudine si forma la subass. più termofila con maggiore partecipazione di specie dei querceti (semi-) decidui a roverella differenziata da *Asparagus tenuifolius*, (*asparagetosum tenuifolii*, typus ril. n. 2), *Lathyrus niger*, *Polygonatum odoratum*, sostituito più in basso da *P. multiflorum*, *Buglossoides purpureocaerulea*; nelle doline

a fondo ampio, argilloso, talvolta inondato si forma la subass. a *Ranunculus ficaria* subsp. *bulbifer* (*ranunculetosum ficariae*, typus ril. n. 8) e *Gagea lutea*. Su suoli lisciviati si costituisce la subass. a *Carex pilosa* (*caricetosum pilosae*, typus ril. n. 8) e *Maianthemum bifolium*; su materiali di crollo o su pendii rupestri, che costituiscono l'ambiente più diffuso dei versanti nord, è stata individuata la subass. a *Dentaria enneaphyllos* (*dentarietosum enneaphylli*, typus ril. n. 15), *Actaea spicata*, *Geranium robertianum*, *Asplenium trichomanes*. I rilievi 11 e 12 non rientrano in nessuno di questi casi e corrispondono alla definizione non più ammessa di "tipico" o di "inops".

Poiché siamo dell'avviso che il condizionamento ecologico più determinante dell'AC sia di natura climatica piuttosto che edafica - su sostrati analoghi ma a minore profondità s'instaura il *Seslerio-Quercetum petraeae* - consideriamo l'AC una vegetazione di tipo extrazonale.

4. Sincorologia

L'AC è endemico del Carso litoraneo nordadriatico ove non ricopre più dello 0,2% della superficie forestale; verso nord a partire dai laghi carsici del Goriziano (Pietrarossa e Doberdò) viene sostituito dall'*Ornithogalo-Carpinetum* che interessa tutta la fascia prealpina delle Alpi sudorientali. Tale sostituzione coincide con quella già ricordata fra *Helleborus odoratus* var. *istriacus* e *H. odoratus* subsp. *laxus*. Verso est lo abbiamo potuto osservare fino alle falde della Vremščica, meno noti sono i suoi limiti meridionali.

Zusammenfassung

Die Waldvegetation die die nordexponierten Abhänge der Karstdolinen im Triester Umland bewächst, wurde schon als *Asaro-Carpinetum betuli* Lausi 64 beschrieben (AC). Weil es aber bei einer synthetischen Tabelle geblieben ist scheint es angebracht eine analytische wiederzugeben, die zugleich die ökologische Gliederung der Assoziation enthält. Die Zugehörigkeit der Gesellschaft zum Verband *Carpinion illyricum* (Horvat) Marinček et al. 1983 ist durch das Vorhandensein von *Primula vulgaris*, *Galanthus nivalis*, *Crocus napolitanus*, *Lonicera caprifolium* gesichert. Dazu gesellen sich andere in Mitteleuropa als *Carpinion betuli* - Arten bewertete Elemente wie *Carpinus betulus* selber, *Lathraea squamaria*, *Prunus avium*, *Crataegus laevigata*, *Carex pilosa*. Das AC verfügt über keine eigenen Kennarten und hebt sich von den anderen Gesellschaften von *Carpinion illyricum* durch die Ass. Diff.-Arten *Isopyrum thalictroides*, *Mercurialis ovata* und *Scilla bifolia* ab. Lokal tragen auch fast alle *Fagetalia*-Arten zu seiner Differenzierung bei, indem AC die einzige *Fagetalia*-Gesellschaft im Bereich des küstennahen Karst darstellt.

Die Ordnungsarten sind reichlich vertreten, worunter *Asarum europaeum* subsp. *caucasicum* p.m.p. die höchste Stätigkeit erreicht. *Fagion illyricum*-Arten wie *Cyclamen purpurascens*, *Lamium orvala* und *Hacquetia epipactis* sind ebenso viele Unterscheidungselemente gegen die Eichen-Hainbuchenwälder nördlich der Alpen. Unter den Klassen-Arten treten die Bestandteile des klimatozonalen Karstwaldes (*Ostyo-Quercetum pubescentis*) wie *Sesleria autumnalis*, *Helleborus odoratus* var. *istriacus*, *Quercus cerris*, *Mercurialis ovata*, besonders regelmässig auf.

Unter den Begleitern ist *Quercus petraea* die hervorragendste, die samt *Q. cerris* und *Carpinus betulus* die Baumschicht ausmacht. Die Abhängigkeit des AC von den geomorphologischen Charakterzügen der Dolinen wird anderswo behandelt (Favretto u. Poldini 1986).

In den weniger tiefen Dolinen bildet sich die Subass. *asparagetosum tenuifolii* mit *Asparagus tenuifolius*, *Lathyrus niger*, *Polygonatum odoratum* und *Buglossoides purpureoacerulea*; und auf Lehm-Schwemmböden des Dolinengrundes bildet sich die Subass. *ranunculetosum ficariae* mit *R. ficaria* subsp. *bulbifer* und *Gagea lutea*.

Auf lissivierten und angesäuerten Böden tritt die Subass. *caricetosum pilosae* auf mit *Carex pilosa*, *Maianthemum bifolium*; auf felsigen Abhängen ist die subass. *dentarietosum enneaphylli* mit *Dentaria*

enneaphyllos, *Actaea spicata*, *Geranium robertianum* und *Asplenium trichomanes* bewiesen.

AC wird für eine extrazonale Vegetation angesprochen weil sie eher von der Temperaturumkehrung abhängt als von der Bodenbeschaffung.

AC ist eine auf den Triester küstenländischen Karst beschränkte Assoziation die nach Norden hin vom *Ornithogalo-Carpinetum* Marinček et all. abgelöst wird.

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Authors' address:
Prof. L. Poldini
Dipartimento di Biologia
cas. Università
I-34100 Trieste

NOTE AI MARGINI DELLA VEGETAZIONE CARSICA

Livio POLDINI *

Keywords: North Adriatic Karst, Trieste, *Arrhenatheretum elatioris*, *Cerastietum pumili*.

Abstract: Notes on the marginal karstic vegetation. The meadows with *Arrhenatherum elatius* and the therophytic coenosis with *Cerastium pumilum* are studied in the North Adriatic Karst (Trieste) with particular regard on its phytogeographical variability.

Con l'abbandono dei pascoli all'evoluzione spontanea le sole cotiche erbacee secondarie che si sottraggono al processo di ricostituzione forestale sono quelle sottoposte allo sfalcio periodico e i pratelli aridi che si sviluppano ai margini delle carraie percorse dai mezzi agricoli. Sono cioè gli arrenatereti, ubicati in prossimità dei villaggi, e l'associazione a *Cerastium pumilum*, tipi quindi ben noti nella letteratura geobotanica per i quali manca però un quadro relativo alla variabilità fitogeografica. Queste note vogliono essere un contributo a colmare tale lacuna.

1. I prati da sfalcio ad avena maggiore

L'*Arrhenatheretum* che si sviluppa nel Carso triestino e goriziano presenta delle caratteristiche peculiari tali da individuarlo nettamente rispetto a quelli descritti per l'Europa centrale e le Alpi.

Le due specie caratteristiche, sono *Arrhenatherum elatius* e *Galium album*, cui possiamo unire le differenziali locali *Lolium perenne*, *Vicia angustifolia* e *Trifolium campestre*, che presentano il massimo sviluppo in questa cenosi, quali differenziali geografiche vanno considerate *Crepis taraxacifolia*, *Achillea collina*, *Knautia illyrica*, *Centaurea vochinensis*.

Mentre *Crepis taraxacifolia* e *Centaurea vochinensis* sono legate prevalentemente a questo tipo di prato, *Achillea collina* e *Knautia illyrica* sono trasgressive da altre cenosi.

Si può pertanto parlare nel nostro caso di una transizione fra una razza delle Alpi sud-orientali, in cui compaiono *Crepis taraxacifolia* e *Centaurea vochinensis*, e l'*Arrhenatheretum litorale* Horvat 1961, differenziato da specie trasgressive dagli *Scorzoneretalia villosae*.

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Tab. 1.

Arrhenatheretum Br. - Bl.ex Scherr. 25, razza carsica

		1	2	
		11111111112222222223333		
	Numero rilievi	123456789012345678901234567890123		
		229944442252434333 2344312434444		
	Altezza s.l.m. (x10m)	004444650437790629987801668552055		
		333322223224332444333334434544233		
	Numero specie	7392308715989763o5346596040501836		Frequenza
Ch	Arrhenatherum elatius	33343333333+22314211	111 +++241	5
	Galium album	1+12+	1111 ++111 + 11+	3
D	Lolium perenne (0)	1+ 1111	+122+1+ + + + +111	3
	Vicia angustifolia	+1+1+	+++2 ++ 1 + + 1	3
	Trifolium campestre	++	2 1+1 + + 3 ++ +	2
	Crepis taraxacifolia +	1 + 1212	+++1+++11 ++1 +++	3
	Achillea collina +	1 22	+1 1+++ + + +1 11++	3
	Knautia illyrica +	+	+1 + 22++ 1 +1	2
	Centaurea vochinensis +	+	+ 1 +	1
d1	Holcus lanatus	112+1 111121	+ 11 +	3
	Myosotis arvensis	++++	++r+++ +	2
	Trifolium patens	221212 3 +		2
	Ranunculus acris	22++ 222		2
	Potentilla reptans	11 12 ++		1
	Lychnis flos-cuculi	++ ++1		1
	Ornithogalum umbellatum	+++ +		1
	Ranunculus repens	1 112		1
d2	Salvia bertolonii	+ + 1++ 11221111	1+11+112	4
	Sanguisorba minor ssp.muricata		+ +r +++++++ +1+ +111	3
	Bromus erectus	++ 1 1 2 334	++1+2+331	3
	Festuca valesiaca	++ + ++1	111+++ + 2+ 1	3
	Veronica arvensis	++ + ++ ++	++1rr+	2
	Briza media	11 1+ 1 1	+++1 11	2
	Thymus pulegioides	1 1	+++++++ 1	2
	Luzula multiflora	+1+	+ +++++ 1	2
	Avenella pubescens (All)	31 34	11 244	2
	Polygala nicaeensis	+	++ + +++ ++	2
	Festuca rupicola		+11 11 1 + +	2
	Anthyllis vulneraria	+	+ + + + ++ ++	2
	Cerastium tenoreanum	+	+ + + ++ + ++	2
	Medicago falcata		+ 11++ + ++	2
	Coronilla varia		++11 ++ + 1	2
	Peucedanum oreoselinum	+	+ + ++ +1	2
	Trifolium rubens	1 1+	2 + 11	2
	Tragopogon tommasinii	+	+r ++ +	1
	Centaurea weldeniana	+2	1 + ++	1
	Pimpinella saxifraga		+1 ++ ++	1
	Viola hirta		+ + ++ +	1
	Scabiosa gramuntia		++ ++ +	1
	Ajuga reptans		+ +++++	1
	Scorzonera villosa		+ + ++	1

	Ferulago campestris		11	+		1
	Lathyrus latifolius		+		+	1
	Dorycnium herbaceum			+		1
All,0	Leucanthemum vulgare		11111	++111++111++1+	2+1 2111	4
	Trisetum flavescens		11+ 1111	2+ +	11 +1++	+ 12 + 3
	Daucus carota		11+	1+	+ +1+++1111	111 3
	Pastinaca sativa ssp. sylvestris		++121	1	++ 1	1 ++ 2
	Bromus mollis		11+11	1	2+ +	+ + 2
	Bellis perennis		++		2	1
	Carum carvi			112		1
	Achillea roseo-alba			+ +		1
	Leontodon autumnalis			++		1
	Carduus collinus				+	+
Cl	Poa pratensis		22123232222233	111+11121212++22		5
	Leontodon hispidus		2211222222122	12 1	2222121113212	5
	Plantago lanceolata		11++11111	11112111111++	+++ 21	5
	Trifolium pratense		11++323211112	1312112212+	++ 2	5
	Taraxacum officinale		11112121111++21+1	+++ 1	1+ 1+ +	4
	Cerastium holosteoides			++1+1+++++1++ 1+	+ ++11++	4
	Rumex acetosa		11++1111111++	+ + 1	+++ +	4
	Rhinanthus minor		4111	111	+ + +	+++ 2
	Lathyrus pratensis			+ ++	++1 +1	11 2
	Vicia cracca		11	1 1		1++ 2
	Festuca pratensis		1	221		+ 1 + 2
	Centaurea jacea		1	11		1
C	Anthoxanthum odoratum		21232322232113	111 212112222132		5
	Plantago media		++11	131111211+1121+3++1123		5
	Lotus corniculatus		1111	111 +11 ++1+1+11++	+++111	5
	Medicago lupulina		1+ ++2+2	112 +121+222+2+	++122	4
	Dactylis glomerata			222222+++++21+22+ 1	++ 111 1 1	4
	Ranunculus bulbosus		++ 1111	211 211 +212+ 211211		4
	Galium verum		1111	1 11 +111	+2	1 3
	Sedum sexangulare			++ ++	+ + ++ ++	2
	Medicago sativa		111111	2 +	+ 1	2
	Veronica chamaedrys		1+	+ +1+		+ ++ 2
	Rhinanthus freynii		1+ 1+	+		1++ 2
	Cerastium glutinosum			1 +	+++1 +	2

1 = Arrhenatheretum holcetosum lanati

2 = Arrhenatheretum brometosum erecti (=Anthoxantho-Brometum Poldini 80)

+ = differenziali geografiche della razza carsica

Tab. 1: Lista delle località

1-2-9-10 Štanjel (YU); 3-4 Aurisina (I); 5-8-30 Grozzana (I); 11 Velike Loče (YU); 12-27 Zagorje (YU); 13 Vrhpolje (YU); 14-23-31-33 Podbreže (YU); 19 Bonetti (I); 20 Ferletti (I); 21 Tupelče (YU); 22 Lukovica (YU); 24 fra Sežana e Divača (YU); 25 Basovizza (I); 26 M. Coisce (I).

Tab. 1: Lista delle sporadiche

Carex caryophylla: (+) 9-10-24-27 (1) 26-32; Euphorbia verrucosa (+) 12-16-20-24-33 (1) 32; Convolvulus arvensis (r) 1-14 (+) 12-17-23-24; Orchis tridentata (1) 7 (r) 18-28-30 (+) 22-29; Centaurea triumfettii (+) 15-17-18-25-27-33; Carex contigua (1) 1-26-32 (+) 3-37; Prunella vulgaris (+) 12-13-14-15 (1) 29; Dianthus sanguineus (+) 12-21-28-29-30; Erigeron annuus (r) 14 (+) 19-26-27-30; Carex pallescens (1) 9-10 (+) 11 (1) 26; Thlaspi praecox (+) 13-25-27-28; Silene vulgaris (+) 18-19-24-25; Orobanche lutea (+) 14-18-28; Rumex crispus (+) 3-7-23; Campanula rapunculus (+) 3-26-27; Chrysopogon gryllus (+) 3 (3) 4 (+) 27; Arabis hirsuta (+) 12-15-16-24; Bromus sterilis (+) 3-12 (1) 4; Vicia hirsuta (+) 16-25 (1) 17; Primula vulgaris (+) 16-25-28; Trifolium montanum (+) 16 (2) 28-29; Arenaria serpyllifolia (+) 17-18-28; Koeleria pyramidata (+) 20-24-26; Polygala comosa (+) 23-26-30;

Aristolochia pallida (+) 24-25-29; *Allium scorodoprasum* (1) 1-2; *Tragopogon orientalis* (+) 1-2; *Vicia tenuifolia* (1) 1 (+) 28; *Knautia drymeia* (2) 3-4; *Calystegia sepium* (1) 3 (2) 4; *Mentha longifolia* (1) 3 (2) 4; *Poa sylvestris* (1) 3 (2) 4; *Dianthus liburnicus* (+) 4-26; *Silene alba* (+) 3-8 (r) 18; *Festuca rubra* (1) 12 (+) 27; *Trifolium molinieri* (1) 12 (+) 25; *Ajuga genevensis* (+) 12-24; *Buphthalmum salicifolium* (+) 13-25; *Salvia verticillata* (+) 15 (1) 17; *Helianthemum ovatum* (+) 19-27; *Brachypodium rupestre* (1) 19-26; *Hypericum perforatum* (+) 20-27; *Petrohragia saxifraga* (+) 22-32; *Hieracium pilosella* (+) 24-33; *Hippocrepis comosa* (+) 24-27; *Orchis morio* (r) 28-30; *Lolium multiflorum* (1) 4; *Cirsium pannonicum* (+) 12; *Filipendula vulgaris* (+) 12; *Carex hirta* (+) 12; *Thymus longicaulis* (1) 13; *Potentilla alba* (+) 13; *Hypericum maculatum* (+) 13; *Helleborus istriacus* (+) 16; *Picris hieracioides* (+) 19; *Euphorbia cyparissias* (+) 20; *Teucrium chamaedrys* (1) 20; *Linum tenuifolium* (+) 20; *Ornithogalum gussonei* (+) 24; *Danthonia alpina* (1) 26; *Senecio jacobaea* (+) 27; *Rhinanthus glacialis* (+) 29; *Cruciata glabra* (+) 33; *Senecio lanatus* (+) 33; *Linum catharticum* (+) 33.

In altre parole, nel gruppo di differenziali geografiche si verifica la commistione di specie di duplice provenienza, per cui è legittimo parlare di una razza di transizione tra l'*Arrhenatheretum litorale* del litorale croato e dell'Istria e quello vallivo delle Alpi Sud-orientali e avanterra alpino.

Molte specie che di solito sono smistate in cenosi diverse si trovano qui all'interno dell'associazione, consentendo di distinguerne due sottotipi: uno più fresco ad *Holcus lanatus*, che occupa doline più profonde ed umide, assieme a *Myosotis arvensis*, *Trifolium patens*, *Ranunculus acris*, *Potentilla reptans*, *Lychnis flos-cuculi*, *Ornithogalum umbellatum* e *Ranunculus repens*, e uno più secco, che era stato descritto come un tipo a sé (*Anthoxantho-Brometum* Poldini 1980), a *Salvia bertolonii*, *Sanguisorba minor* ssp. *muricata*, *Bromus erectus* unitamente a un complesso di specie provenienti dal contiguo *Danthonio-Scorzoneretum*. Interessante notare che *Avenella pubescens*, in letteratura indicata quale specie caratteristica di *Arrhenatherion*, nell'*Arrhenatheretum* carsico si comporta come differenziale del sottotipo più arido.

L'*Arrhenatheretum* è attualmente l'unica forma superstita di prato costantemente concimato e sfalcato; il sottotipo più diffuso è senz'altro quello arido a *Bromus erectus*.

2. I pratelli aridi a *Cerastium pumilum*

La classe dei *Sedo-Scleranthetea* da noi sembra essere rappresentata solo dall'ordine dei *Sedo-Scleranthetalia* e dall'unica alleanza *Alyssoidi-Sedion albi*.

In un primo momento Poldini (1980) aveva pensato di istituire una nuova cenosi basata sulla presenza di *Crepis neglecta* (*Crepido neglectae* - *Trifolietum scabri*). In questa sede si preferisce ritornare al concetto estensivo di associazione assimilando le variazioni territoriali alla definizione di razza geografica locale.

Fra le specie caratteristiche ritroviamo *Trifolium scabrum*, *Cerastium pumilum*, *Arabis auriculata*, *Cerastium brachypetalum*. Ben rappresentate pure le specie di alleanza quali *Saxifraga trydactylites*, *Tortella inclinata*, *Micropus erectus*, quest'ultimo talvolta presente anche nei *Crisopogoneti* del Carso monfalconese e goriziano.

L'ordine è testimoniato da *Sedum sexangulare*, *Teucrium botrys*, *Petrohragia saxifraga*, *Alyssum montanum*, *Allium montanum*.

Le specie di classe sono: *Arenaria serpyllifolia*, *Poa bulbosa*, *Plantago lanceolata*, *Taraxacum laevigatum*, *Medicago minima*, *Erophila verna* etc.

Il *Cerastietum pumili* colonizza soprattutto i margini e la parte centrale delle antiche mulattiere e carrarecce del Carso, non disturbate dal passaggio delle ruote.

Alcuni dei suoi elementi provengono dalle "pelouses" mediterranee (*Thero-Brachypodietea*) da una parte, e dall'altra esiste una penetrazione abbondante di specie di cotiche erbacee più evolute (*Festuco-Brometea*) quali *Sanguisorba minor* ssp. *muricata*, che concorre alla caratterizzazione fitogeografica, *Medicago lupulina*, *Ranunculus bulbosus*, *Bothriochloa ischaemon*, *Festuca valesiaca*, *Festuca rupestris*; sono numerose anche le specie ruderali.

Sedo-Scleranthetea e *Thero-Brachypodietea* possono essere considerate classi di vegetazione equivalenti da un punto di vista edafico, ma legate a bilanci termici diversi; la prima gravita infatti nell'Europa continentale temperata la seconda nel Mediterraneo.

La presenza contemporanea sul Carso litoraneo di elementi appartenenti alle due classi è un'ulteriore testimonianza del significato di soglia biogeografica (bioclimatica) di questo territorio.

I primi 21 rilievi sono meglio dotati di specie caratteristiche di associazione mentre l'ala estrema è priva di caratteristiche di associazione e di alleanza, sono presenti soltanto caratteristiche di rango superiore. Questi rilievi rappresentano quindi un'espressione impoverita.

3. Fenologia del *Cerastietum pumili*

Il *Cerastietum pumili* è stato seguito settimanalmente per due anni (1983-84) durante l'arco di fioritura per verificare se nelle condizioni climatiche generali del Carso, un impoverimento e una maggior percolabilità del substrato determinassero un'accentuazione del minimo estivo della curva bimodale di fioritura che era stata rilevata nel *Lactuco-Ischaemetum* (Poldini, 1975).

Pure nel *Cerastietum pumili* si verifica un'interruzione estiva, anche se non accentuata rispetto al *Lactuco-Ischaemetum*, ma con inversione dei massimi rispetto a questo: il massimo assoluto si verifica in primavera, ed è dovuto principalmente all'affollamento delle terofite primaverili che non compaiono nel *Lactuco-Ischaemetum*, dove prevale invece la fioritura delle graminacee serotine (fig. 1).

L'interruzione estiva è meno accentuata proprio perché ci troviamo ormai nell'ambito di un clima submediterraneo-subcontinentale.

Dall'analisi dello spettro analitico, fig. 2, si vede che la prima fioritura è determinata da *Erophila verna*, *Poa bulbosa* e *Taraxacum laevigatum*, mentre quella tardo-primaverile e inizio estate da *Crepis neglecta* e *Trifolium scabrum*.

Le specie che contribuiscono ad impartire al grafico sintetico i due massimi sono *Erodium cicutarium*, *Geranium molle*, *Lolium perenne*, *Geranium purpureum*, *Medicago minima*, *Plantago lanceolata*, *Medicago lupulina*, *Geranium columbinum*, *Satureja acinos*, che hanno appunto due periodi di fioritura.

Il massimo assoluto deriva quindi dalla somma delle fioriture delle terofite e delle specie rifiorienti.

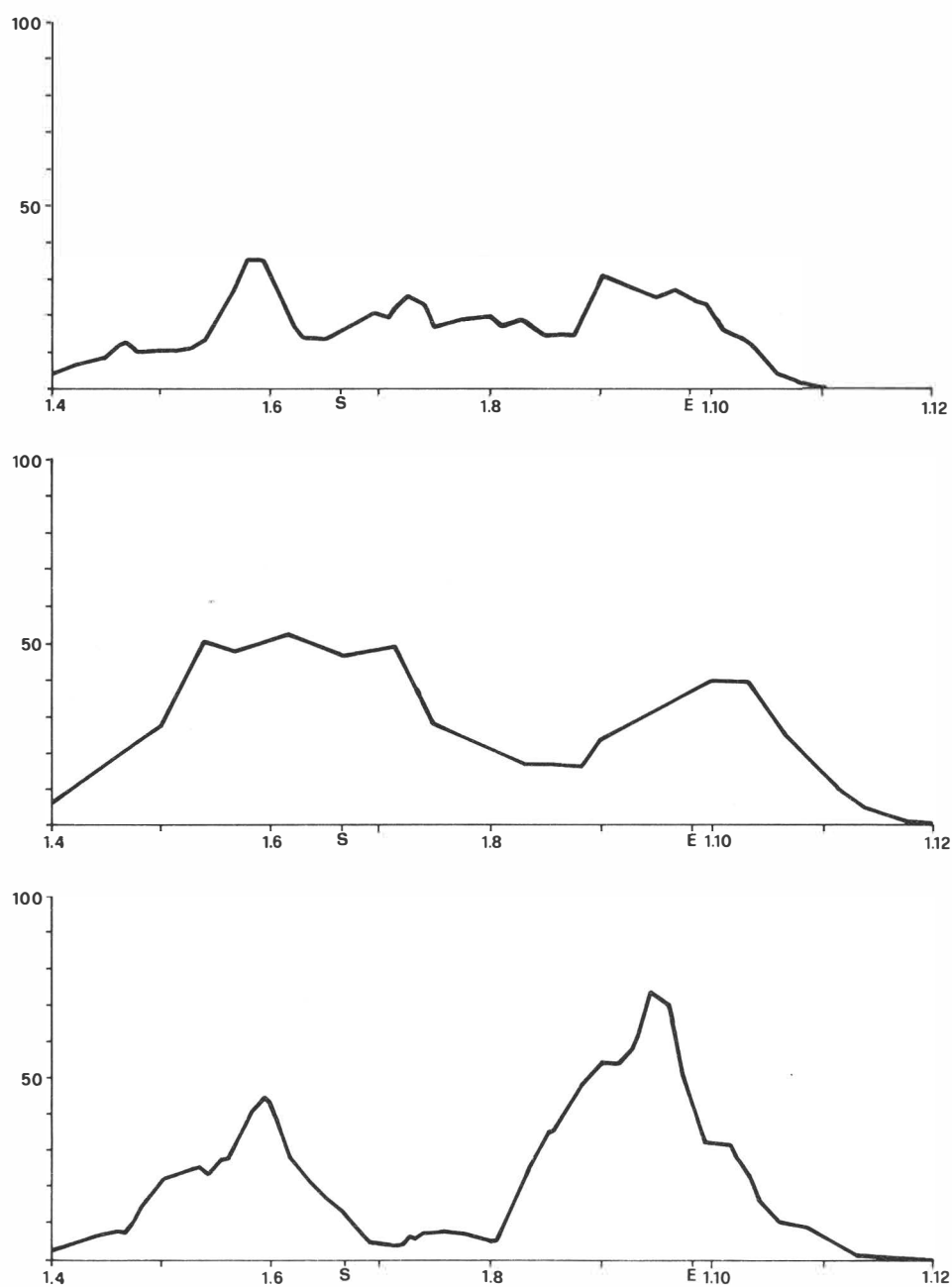


Fig. 1 — Diagramma antesico di: *Carici-Centaureetum rupestris* (sopra), *Cerastietum pumili* (in mezzo), *Chrysopogono-Centaureetum rupestris* (sotto).

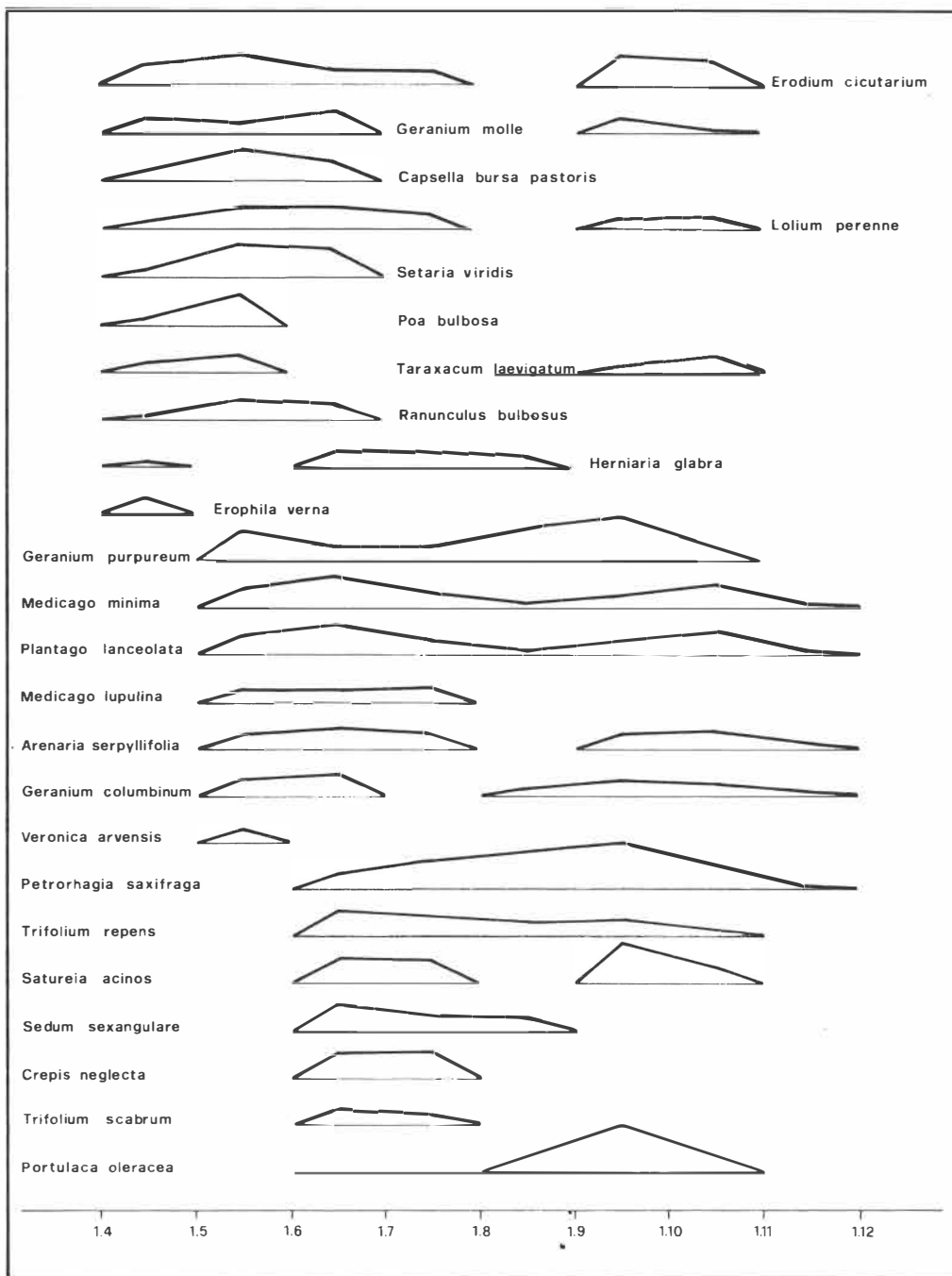


Fig. 2 — Spettro analitico del *Cerastietum pumili* rilevato negli anni 82-83.

Tab. 2

Cerastietum pumili Oberd. et Mull.in Th. Mull. 61 Razza carsica

(=Crepido neglectae-Trifolietum scabri Poldini 80)

		1111111111222222222										
Numero rilievi		12345678901234567890123456789										
Altezza s.l.m. (X 10m)		3333423334 22 3222 22213 3 9884027002 99 6592 884854 8										frequenza
Numero specie		3233321212111111121211121112 06011773977370633781617424629										
Ch	Trifolium scabrum	12312+1 +1212+111										3
	Cerastium pumilum	+1+ + +++										2
	Crepis neglecta +	++1+ r+ 1										2
	Arabis auriculata	r +										1
	Cerastium brachypetalum	+ 1										1
All	Saxifraga tridactylites	+1+1++ + + 11 + +										3
	Tortella inclinata	2 13 3 2132313										2
	Alyssum alyssoides	+++ + 1+ +										2
	Lathyrus sphaericus	r + + r										1
	Micropus erectus	+ +										1
O	Sedum sexangulare	1+21221 41 3233342 11 ++ 3+										4
	Petrorhagia saxifraga	+211+ + 11 11 11 1 +										3
	Teucrium botrys	+ + 1 r +										1
	Alyssum montanum	+ +										1
	Allium montanum	3										1
Cl	Arenaria serpyllifolia	++ ++++11++ +1 +++ +1 1+										4
	Poa bulbosa	14113221 11 + 3 1233 11										4
	Plantago lanceolata	+++++r1 111 +++ 1 +										3
	Taraxacum laevigatum	++++r++ 11 + + +1+										3
	Medicago minima	1 11 1 1+ 3 12 +2+ 3										3
	Erophila verna	+1 11 r 11 + 11 1										2
	Calamintha acinos	+ 1+++ ++r + +										2
	Erodium cicutarium	+ + + 2 2 1+ + + +										2
	Veronica arvensis	1 + r+ + 1+1										2
	Catapodium rigidum	r r 1 + 1 + +1										2
	Syntrichia ruralis	1 33 31										1
	Trifolium campestre	1 1+ +										1
	Vulpia myuros	1 1+ +										1
	Echium vulgare	+ 1 +										1
	Cerastium glutinosum	++1										1
	Herniaria glabra	+ +										1
	Scleranthus annuus	+										1
	Cerastium semidecandrum	+										1
	Vulpia ciliata	+										1

	Valerianella locusta					1		1
C	Setaria viridis	1	1r1	+	11212	14	+11r	3
	Sanguisorba minor ssp. muricata	+	+	++	+r	+	+	11
	Medicago lupulina	+12	+	111	+	+	r	+
	Eragrostis tenuis	1	+1	1+	1	1+1	+2	1
	Lolium perenne	+11+		2		1	++1	3
	Ranunculus bulbosus	+	1		++	1	+++	1
	Diploaxis tenuifolia		+	++		+	+	+++
	Bothriochloa ischaemon	+	+	++	+		311	
	Trifolium repens	1	11		12	+	1	2
	Thymus longicaulis	2++		1		+1	1	
	Centaurea cristata				+	r	2	++
	Festuca valesiaca	1+			+	1+	+	
	Plantago media	++	+		++	1		
	Festuca rupicola	1	+1	1	1			
	Geranium molle	1+		+		++	+	
	Eragrostis pilosa	+		1	31	1		1
	Geranium columbinum	+++	+				3	+
	Poa compressa	++	+	+	r			+
	Dactylis glomerata	+++		++			+	
	Scabiosa gramuntia			++			+	++
	Tragus racemosus				11111			

+ = differenziale di razza geografica

Tab. 2 - Lista delle località

1 Škocjan (YU); 2-3-16 Zolla (I); 4 Rupingrande (I); 5-10 Merče (YU); 6-17 Strada Napoleonica (I); 7 Basovizza (I); 8 M. Radio (I); 9-27 Percedol (YU); 11 Sales (I); 12-15 Precenico di Sopra (I); 13-14 Rupinpiccolo (I); 18-24 Volčji grad (YU); 19-22 Pliskovica (YU); 20-28 Aurisina (I); 21-25 M. Gurca (I); 23 Krajna vas (YU); 26-Vallone di Gorizia (I); 29 Colle dell'Anitra (I).

Lista delle sporadiche:

Bupleurum veronense: (+) 1-5, (r) 8, (1) 20; Geranium pusillum: (+) 5-9, (1) 13, (r) 16; Euphorbia cyparissias: (+) 8-15-26-28; Portulaca oleracea: (2) 13-16, (+) 14, (r) 19; Capsella bursa-pastoris: (+) 18-22-23-24; Koeleria splendens: (1) 1-20, (+) 4; Achillea collina: (+) 2-23-27; Plantago major: (+) 4, (r) 27, (1) 29; Erigeron strigosus: (+) 8-20-28; Bromus madritensis: (+) 8-21, (1) 26; Vicia sativa (angustifolia): (+) 18-24-28; Bromus sterilis: (+) 18-28, (1) 25; Geranium purpureum: (r) 18, (+) 25, (1) 26; Potentilla tommasiniana: (2) 1, (+) 7; Stellaria media: (+) 2, (r) 5; Bromus mollis: (+) 3-18; Lactuca serriola: (r) 3, (+) 21; Cleistogenes serotina: (+) 3-28; Hypericum maculatum ssp. veronense: (+) 6-8; Bupleurum junceum: (+) 8-17; Medicago prostrata: (+) 8-26; Teucrium chamaedrys: (1) 8, (+) 28; Verbascum chaixii: (+) 8-28; Artemisia absinthium: (+) 9-27; Bromus squarrosus: (+) 9-27; Galium album: (+) 10, (r) 22; Potentilla recta: (+) 10-28; Lotus corniculatus ssp. hirsutus: (+) 11, (r) 20; Satureja montana ssp. variegata: (+) 12-20; Sonchus asper: (+) 17, (1) 25; Allium sphaerocephalon: (+) 17-21; Convolvulus arvensis: (+) 18, (r) 25.

Zusammenfassung

Es werden die pflanzensoziologischen aus dem nordadriatischen im Umland von Triest und Görz liegenden Karst von *Arrhenatheretum* Br.-Bl. ex Scherr. 25 und *Cerastietum pumili* Oberd. et Müll. in Theo Müll. 61 stammenden Tabellen veröffentlicht, wobei besondere Aufmerksamkeit der pflanzengeographischen Variabilität geschenkt wird.

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Authors' address:
Prof. L. Poldini
Dipartimento di Biologia
Cas. Università
I-34100 Trieste

URBAN LICHEN STUDIES IN ITALY Ist: THE TOWN OF TRIESTE

Pier Luigi NIMIS *

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Abstract. This paper reports on the distribution of lichens in the urban environment of Trieste (NE-Italy) and its surroundings. The study is based on 213 phytosociological relevés, taken on trees with primarily acid bark, and on pollution data from a net of deposimetric stations located within the town center. Both data sets have been submitted to multivariate analysis (classification and ordination). The results of data analysis allowed to distinguish six main zones, three defined by a peculiar lichen vegetation, the remaining three delimited on the basis of pollution data. The ecology of the releve groups obtained by classification has been studied on the basis of the tolerance ranges associated to each species by Wirth (1980). From the periphery to the center of the town there is a decrease in species, and an increase in the relative frequency of xero- photo- nitro- and neutro-basiphytic species. The distribution of lichens within the survey area cannot be explained on the only basis of air pollution. Drought in the urban environment seems to be another important factor affecting the distribution of lichens in the town of Trieste.

Introduction

Lichens have been often claimed to be good indicators of air pollution (for a review of the abundant literature on this subject see Ferry et al., 1973). Some authors, however, (Beschel, 1958; Rydzak, 1969) thought that drought in urban environments is the main cause of the scarcity of lichens in towns. The latter hypothesis was strongly criticized, above all by authors working in Western Europe (see Coppins, 1973). The number of towns whose lichen floras have been studied in connection with pollution studies is very high. Zone-maps have been drawn for many of them and scales have been worked out by means of which it seems possible to predict pollution levels from features of the lichen flora and vegetation. Nevertheless, such scales are obviously valid only within areas with a given lichen flora and with given climatical conditions. Most of them (see Barkman, 1958; Hawksworth & Rose, 1970) refer to Northwestern Europe, that has an oceanic - suboceanic climate, and their use in Italy is problematic. To my knowledge, up to now only three studies have been published on lichens and air pollution in Italy. The first refers to a mountain valley in the Eastern Alps (Caniglia et al., 1978): 5 species are mentioned and the study is mainly centered on *Xanthoria parietina* and *Physconia pulverulacea*. The second was carried out in a small village in the Western Alps (Pierivittori & Montacchini, 1980), and cites 8 species. The last (Caniglia &

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Drudi, 1984) concerns the lagoon of Venice, where, according to the authors, 31 species are present (on all kinds of substrate).

This paper is the first of a series whose subject is the study of epiphytic lichens in urban environments within the Italian territory. The first three papers of the series treat the towns of Trieste (this paper), Udine (Nimis, 1986) and Rome (Nimis, in prep.). Aim of these papers is simply the analysis of distribution patterns of lichen species in the three towns, in order to provide a basis for further studies on lichens as indicators of air pollution in the Italian territory.

Description of the survey area

The town of Trieste is located in NE Italy, at Lat. 45°40' N, Long. 13°46' E. The elevation goes from sea level to 405 m at the edge of the Karst Plateau. The population is of 257.697 people (data of 1980). The phanerogamic vegetation of the surroundings of Trieste has been the object of several studies (Lausi & Poldini, 1962; Poldini, 1972, 1975, 1980, 1981, 1982). A characteristic of Trieste is the complete absence of extensive cultivations in the surroundings of the town, so that there is a relatively sharp transition between a urban and a semi-natural environment, the latter mainly characterized by rather well developed *Quercus*-woods. The lichen flora of some sites in the surroundings of the town has been studied by Nimis & Loi (1982a and b, 1984) and Nimis & Losi (1983). The epiphytic lichen vegetation has been studied by Nimis & De Faveri (1981) and Nimis (1982).

The climatic diagram of the town is in Fig. 1. The climate is transitional between the mediterranean and the continental climate types, with relatively strong differences between the coastal strip and the inner, more elevated portion of the area. Mean yearly precipitation in Trieste is 952 mm (Fig. 1), whereas on the Karst

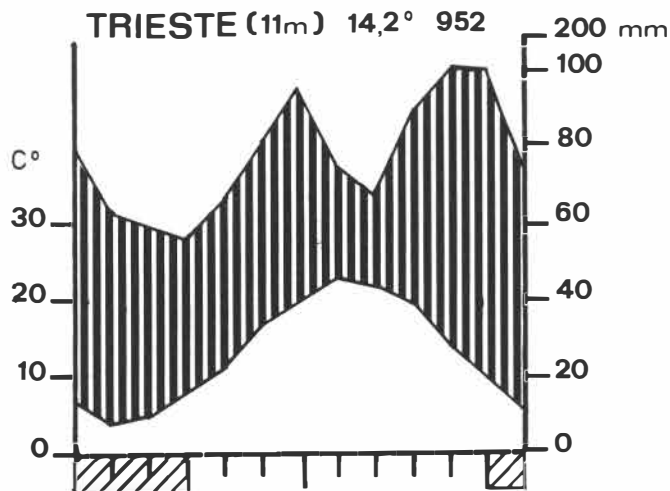


Fig. 1 — Climatic diagram of Trieste.

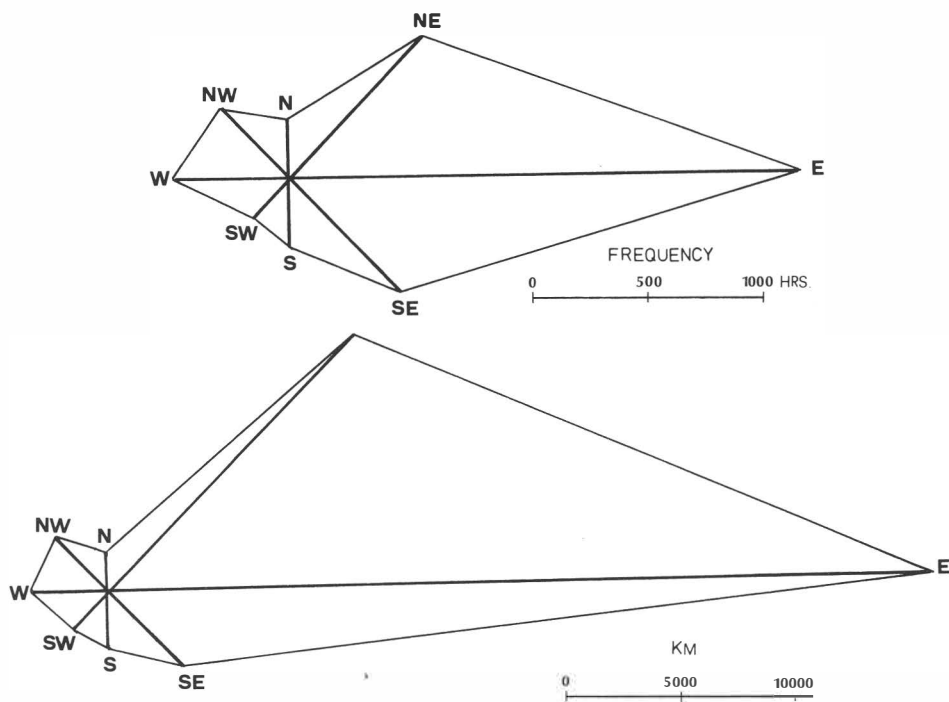


Fig. 2 — Average yearly wind speed and wind frequency in the town of Trieste (redrawn from Polli, 1971).

plateau (Opicina) it is 1157 mm (Polli, 1961). Mean yearly temperature in Trieste is 14.2° C, in Opicina 11.1° C. The climatic diagram of Trieste (Fig. 1) shows a maximum of precipitation in Autumn. The area is frequently subject to strong dry winds blowing from ENE (Bora) (Fig. 2); they are particularly frequent in winter, when the speed may be over 120 Km/h. A warm-humid wind blows from SW (Scirocco), normally bringing rainy weather. The prevailing action of the Bora-wind and the low water-holding capacity of the limestone rocks surrounding the town contribute to relatively low air humidity (average 65%, Poldini 1980) throughout the year.

Data and methods

A reference grid with squares of 500 m has been superimposed to the map of Trieste (see Fig. 3). In some cases (particularly hills where the same subdivision includes areas with different exposure) the adopted squares had a side of 250 m. The squares constitute the reference for drawing maps concerning the distribution of lichens. The survey area (Fig. 3) includes the town itself, plus the edge of the Karst Plateau, with the village of Opicina. The outskirts of the town are occupied by a semi-natural vegetation dominated by oaks (*Quercus pubescens* on limestone,

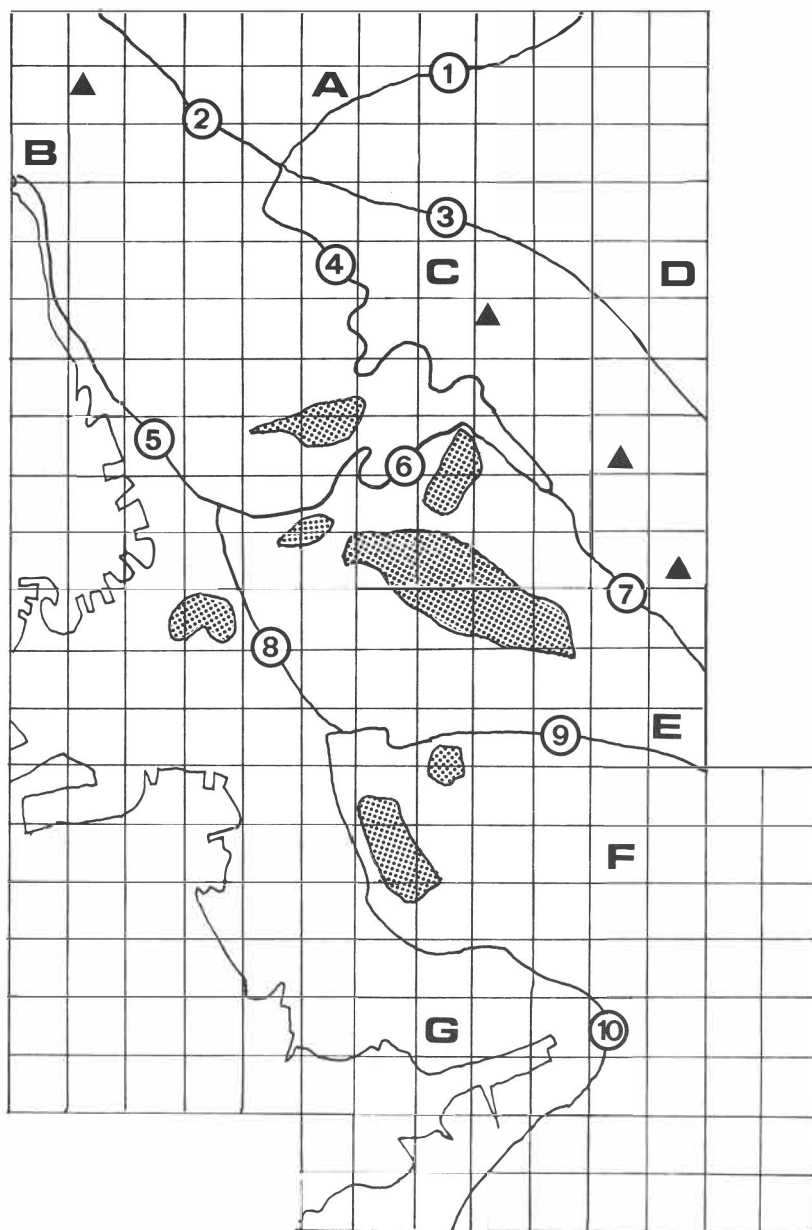


Fig. 3 — Map of Trieste with reference grid. Circled numbers refer to main roads, as follows: 1) Via Nazionale, 2, 3) SS 202, 4) Strada Nuova per Opicina, 5) Viale Miramare, 6) Via F. Severo, 7) Strada per Basovizza, 8) Via Carducci, 9) Autostrada, 10) Via Flavia. Letters refer to main villages in the hinterland: A) Opicina, B) Barcola, C) Banne, D) Trebiciano, E) Melara, F) S. maddalena Inf., G) Industrial area. Dotted areas are the main parks within the urban area proper. The triangles indicate the main peaks along the ridge of the Karst Plateau.

Quercus petraea on sandstone), and several green areas are available within the town for sampling of epiphytic lichens. As porophytes, trees were selected whose bark is primarily acid. These are (in order of frequency): *Quercus*, *Robinia*, *Tilia*, *Aesculus*, *Platanus*. Relevés were taken at the North and South sides of the boles, at the base and at 1.5 m up on the bole, within squares of 50 cm. Each subdivision of the town is represented by 1 to 5 porophytes. A relevé consists in a complete species list, with cover values according to the cover/abundance scale of Braun-Blanquet (1964). Severe damage (decortication) of species was also recorded when evident in more than 20% of the specimens present in the plot. Sampling was carried out in 1981 and in the first half of 1982.

Pollution data were kindly supplied by the Laboratorio di Igiene e Profilassi della Provincia di Trieste (Dr. Severi). They are averages of 5 years long measurements in a net of 28 deposimetric stations, mostly located within the urban area of Trieste. They concern: insoluble substances, soluble substances, ashes of soluble and insoluble substances (the difference gives the amount of organic material), ions Cl, SO, Ca, Mg: these measures are obtained by analysis of the soluble substances, and are related to pollution by industries and traffic (chloridric acid, sulphur dioxide, dust). No direct measurements of the concentration of sulphur dioxide within Trieste were available.

Both floristic and pollution data have been submitted to multivariate analysis (classification and ordination), as follows:

- a) Classification, in order to detect groups of similar cases (relevés, deposimetric stations), or variables (species). Complete Linkage Clustering (Anderberg, 1973) was used, with correlation coefficient as similarity measure in the case of floristic data (presence-absence values), and similarity ratio (see Westhoff & Van der Maarel, 1973), after data standardization, in the case of pollution data (quantitative data).
- b) Concentration Analysis (AOC, Feoli & Orloci, 1979), on the contingency table of species and relevé groups, in order to quantify their respective correlations.
- c) Ordination, both for relevés and deposimetric stations, in order to test the existence of compositional or pollution trends. Principal Component Analysis has been used (see Orloci, 1978), with similarity ratio on quantitative data, after standardization (both for relevés and stations).

A further data source, utilized for the ecological interpretation of relevé groups, are the tolerance ranges assigned to each species by Wirth (1980). They concern: pH, light, moisture and nitrates. Furthermore, direct data on the pH of the bark were obtained for 138 trees: 2 g of pulverized bark have been left in 16 ml of distilled water for 24 h, and the pH was measured with a digital pH-meter.

The distribution of the relevé groups and of the groups of deposimetric station obtained by classification has been reported on maps, and the results of data analysis have been used to discuss the main factors affecting the distribution of lichens in the urban environment of Trieste. A zone-map has been constructed, chiefly based on the distribution of relevé and station groups, with minor modifications derived by subsequent observation of lichen vegetation within

subdivisions of the town that were particularly "critical" (top of hills, border zones between two areas in which a given vegetation type is prevalent etc.)

Results

Analysis of pH and floristic data

The pH of the bark of the 5 porophytes selected for sampling is as follows: *Quercus pubescens* + *Q. petraea* (53 measures) 4.7 at 1.5 m, 5.0 at tree base; *Robinia pseudacacia* (25 measures): 5.3 at 1.5 m, 7.0 at tree base; *Tilia cordata* (20 measures): 5.5 at 1.5 m, 7.0 at tree base; *Aesculus hippocastanus* (20 measures): 5.6 at 1.5 m, 6.8 at tree base. *Platanus orientalis* (20 measures): 6.1 at 1.5 m, 6.9 at tree base. The pH at tree base is around 7.0 for all of the species except *Quercus*. The reason is that at tree base accumulation of dust and nitrates is higher, above all on trees located along roads. *Quercus* is never planted as a wayside tree in the study area, and most of the relevés on this porophyte have been taken in natural or semi-natural vegetation outside of the most heavily urbanized areas, where accumulation of nitrates at the base of the boles is lower.

The results of the classification of relevés and species are shown in Fig. 4. Five

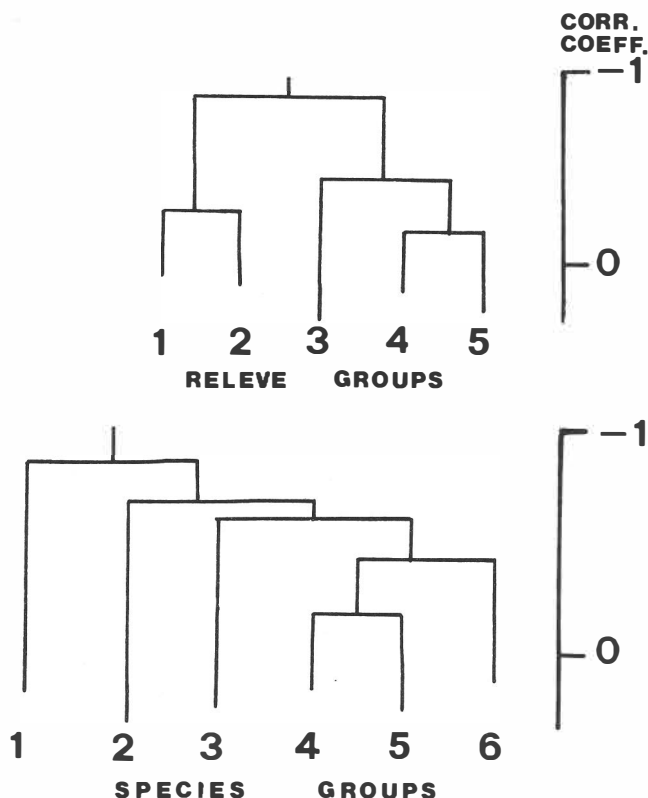


Fig. 4 — Dendrograms of relevé and species groups.

main releve groups and six main species groups are formed. The relative frequencies of the species in the releve groups are in Tab. 1. The degrees of

S.P.G.R. No.	SPECIES	RELEVE GROUPS				
		1	2	3	4	5
1 1	Evernia prunastri	* 100.0 (+)	10.5 (+)			
1 2	Hypogymnia physodes	* 91.6 (1)	5.2 (+) _o			
1 3	Usnea hirta	* 41.6 (+)	5.2 (+) _o			
1 4	Parmelia subaurifera	* 66.6 (2)	31.6 (1)		23.1 (+)	
1 5	Parmelia caperata	* 100.0 (3)	63.1 (2)	10.0 (1)	15.4 (1)	13.6 (+) _o
1 6	Parmelia sulcata	* 100.0 (3)	47.3 (3)	20.0 (1)	46.1 (1)	9.1 (+) _o
1 7	Parmelia tiliacea	* 66.6 (2)	36.8 (2)	20.0 (1)	7.7 (+)	4.5 (+) _o
1 8	Parmelia subrudecta	* 83.3 (1)	73.6 (1)	60.0 (1)	15.4 (1)	11.3 (+) _o
2 9	Parmelia glabra	*		100.0 (4)		
2 10	Parmelia quercina	*		100.0 (1)		
2 11	Parmelia acetabulum	*		80.0 (3)		
2 12	Parmelia exasperata	* 16.6 (+)	5.2 (+)	60.0 (+)	6.3 (+)	
3 13	Normandina pulchella	* 8.3 (+)	5.2 (+)	10.0 (+)		
3 14	Caloplaca ferruginea	*	10.5 (1)	10.0 (+)		
3 15	Cladonia fimbriata	* 8.3 (+)				2.3 (+) _o
3 16	Cladonia coniocraea	* 8.3 (+)				2.3 (+) _o
3 17	Lecanora symmictera	* 8.3 (+)				
3 18	Buellia punctata	* 8.3 (+)	5.2 (+)			4.5 (+)
3 19	Ramalina fastigiata	* 8.3 (+)			7.7 (+) _o	
3 20	Scoliosporum chlorococcum	* 16.6 (+)				4.5 (+)
4 21	Physciopsis adglutinata	*			7.7 (+)	
4 22	Candelariella reflexa	* 75.0 (1)	21.0 (+)		76.9 (1)	22.0 (+)
4 23	Lecidella elaeochroma	* 50.0 (1)	42.1 (1)		76.9 (2)	22.7 (1)
4 24	Physcia biziana	* 33.3 (+)	31.6 (+)		92.3 (2)	56.8 (+) _o
4 25	Parmelia exasperatula	*	7.7 (+)		15.4 (+)	
4 26	Lecanora hageni	*			7.7 (+)	2.3 (+)
5 27	Lecanora chlorotera	* 16.6 (+)	15.7 (+)	40.0 (1)	76.9 (2)	6.8 (+)
5 28	Xanthoria parietina	* 8.3 (+) _o	36.8 (+)	60.0 (1)	84.6 (1)	56.8 (+) _o
5 29	Physconia pulverulacea	*	47.3 (1)	60.0 (2)	84.6 (2)	56.8 (+) _o
5 30	Physconia grisea	*	36.8 (+)		23.1 (1)	4.5 (+)
5 31	Candelaria concolor	* 25.0 (+)	21.0 (+)	20.0 (1)	76.9 (1)	34.1 (1)
6 32	Candelariella xanthostigma	*		10.0 (+)	23.1 (+)	6.8 (+)
6 33	Physcia aipolia	* 8.3 (+)			15.4 (1)	15.9 (+) _o
6 34	Rinodina exigua	*			15.4 (+)	2.3 (+)
6 35	Lecanora carpinea	*	5.2 (+)		15.4 (1)	2.3 (+)
6 36	Caloplaca viperae	*	7.7 (+)		7.7 (1)	
6 37	Caloplaca cerina	*			7.7 (1)	4.5 (+)
6 38	Caloplaca holocarpa	*	5.2 (+)		15.4 (1)	9.1 (+)
6 39	Caloplaca flavorubescens	*			7.7 (+)	4.5 (+)
6 40	Xanthoria fallax	*			7.7 (+)	4.5 (+) _o
6 41	Physcia orbicularis	* 16.6 (+)	21.0 (+)		23.1 (1)	54.5 (1)
6 42	Physcia adscendens	* 38.3 (+)	40.9 (+)	20.0 (+)	59.2 (2)	88.6 (1)
6 43	Lecanora atra	*				2.3 (+)

Sporadic species: Gr.1: Parmelia perlata, Lecidella euphorea, Collema subnigrescens, Physcia pusilloides, Arthonia radiata, Opegrapha atra, Lecanora pallida.
 Gr.2: Collema subfurvum, Collema ligerinum, Pertusaria albescent, Physcia luganensis, Physcia hirsuta, Lepraria incana.
 Gr.3: Bacidia rubella, Anaptychia ciliaris.
 Gr.4: Physcia tenella, Lecania cyrtella, Catillaria nigroclavata, Parmelia glabratula, Arthopyrenia punctiformis, Physcia nigricans.
 Gr.5: Lecanora conizaeoides.

Tab. 1 — Frequency and average cover (in brackets) of the species in the five releve groups obtained by numerical classification of the 213 phytosociological releves.

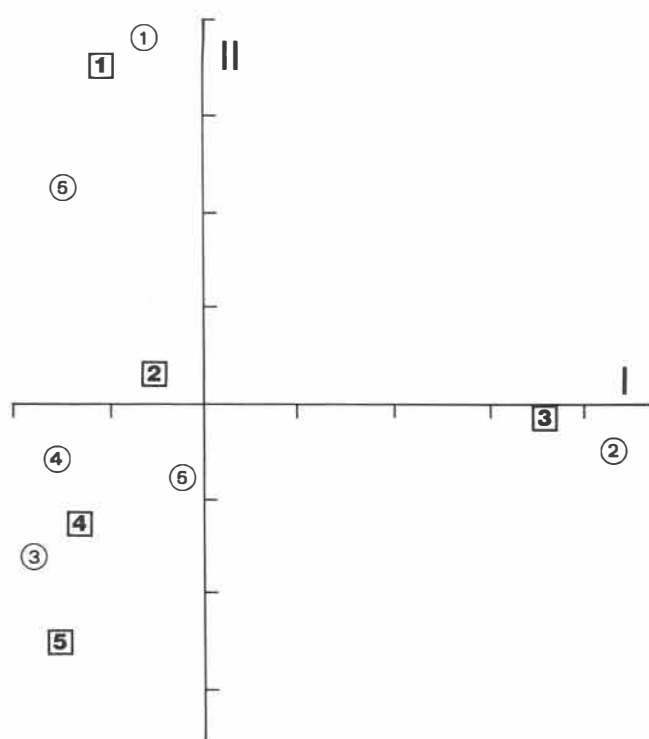


Fig. 5 — Arrangement of releve group and species group - points according to the first two canonical variates of AOC, performed on the contingency table of species and releve groups, as obtained by numerical classification of the matrix of species and releves. Numbers within circles refer to species groups, numbers within squares to releve groups, as in Tab. 1.

correlation between releve and species groups have been quantified by AOC, performed on the contingency table of species groups and releve groups. The results are shown in Fig. 5. The first canonical variate (Fig. 5) clearly separates releve group 3 and species group 2 from the others. Along the second canonical variate the remaining releve groups are arranged in the following sequence: 1, 2, 4, 5, and the species groups in the following sequence: 1, 3, 4, 5, 6. Releve group 1 is clearly correlated with species group 1, releve groups 4 and 5 with species groups 6, 4 and 5, releve group 2 is in an intermediate position between releve groups 1 and 4, 5. The five releve groups may be briefly characterized as follows:

Gr. 1: Mainly characterized by species of group 1. Most of them have their optimum in unions of the order *Parmelietales physodo tubulosae*. Total number of species: 32; mean species number: 11.04, average cover: 80%. Mainly within woods, on *Quercus* at all exposures, mostly at 1.5 m (the base of the boles of *Quercus* within woods is mostly covered by mosses; see Gerdol, 1982), rarely on isolated trees and then always at the N-side of the bole. Constant species are *Evernia prunastri*, *Parmelia caperata* and

Parmelia sulcata; high frequency species are *Hypogymnia physodes* and *Parmelia subrudecta*. The floristic composition of this releve group corresponds well to the one of the *Parmelia* spp. vv. sociation, that, according to Nimis (1982) is the most frequent epiphytic lichen synusia in the *Quercus*- woods of the Karst Plateau near Trieste, outside deep dolines.

- Gr. 2: This releve group is not characterized by any species or species group. Although it is floristically similar to releve group 1 (Fig. 4), it contains also many species occurring in releve groups 4 and 5. No species is present in all of the releves. High frequency species are: *Parmelia subrudecta*, *Parmelia caperata*, *Physconia pulverulacea* and *Parmelia sulcata*. The total number of species is 32, mean species number is 6.4, and average cover is 60%. Mostly at 1.5 m, on isolated trees (*Quercus*, *Robinia*, *Tilia*) North-exposed. For the absence of any differential species, this group cannot be assigned to any clearly defined vegetation type, and is transitional between the *Parmelietales* and *Physcietales* Orders.
- Gr. 3: This group, including only 10 releves, is very well defined by the very high correlation with species group 2, including, in order of frequency: *Parmelia glabra*, *Parmelia quercina*, *Parmelia acetabulum*, *Parmelia exasperata*. Other frequent species are *Parmelia subrudecta*, *Xanthoria parietina* and *Physconia pulverulacea*. Floristically, this releve group can be easily assigned to the *Parmelietales acetabulae*, that according to Nimis (1982) in the Trieste Karst mainly occurs on isolated trees in wind swept areas. Total number of species: 18, average species number: 6.8, mean cover: 90%. Mainly North-exposed, on isolated trees (*Tilia* and *Quercus*) at 1.5 m.
- Gr. 4: This releve group is mainly correlated with species groups 5 and 6. The most frequent species are: *Physcia biziana*, *Xanthoria parietina*, *Physconia pulverulacea*, *Lecidella elaeochroma*, *Candelariella reflexa*, *Lecanora chlorotera* and *Candelaria concolor*. Total number of species: 35, mean species number: 10.6, mean cover: 60%. Always on isolated trees (all of the 5 porophytes), both at tree base and at 1.5 m, mostly South-exposed (just 2 releves at tree base, North-exposed). Floristically, this releve group corresponds with the *Physcietum adscendentis physciosum bizianae* (Nimis & De Faveri, 1981; see also Nimis 1982), a variant of the *Physcietum adscendentis* that in NE-Italy is restricted to the coastal strip in the Province of Trieste.
- Gr. 5: This releve group has no differential species in respect with the previous one. The main differences are that releve group 5 has a much lower mean species number (4.9), and fewer high frequency species. These are: *Physcia adscendens*, *Xanthoria parietina*, *Physconia pulverulacea*, *Physcia biziana* and *Physcia orbicularis*. The average cover is less than 10%, and many species had poorly developed thalli with frequent damages to the upper cortex (see Tab. 1). The group is here considered as an impoverished facies of the community typically represented by releve group

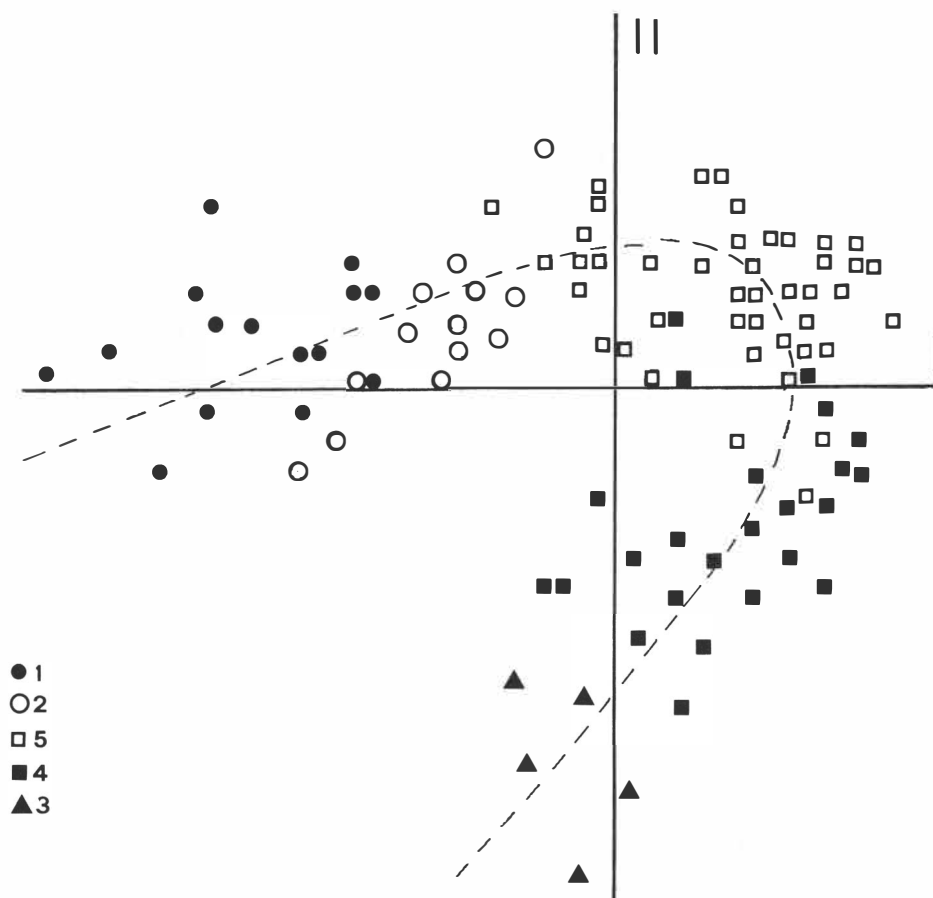


Fig. 6 — Ordination of relevés. Arrangement of relevé points according to the first two principal components. Symbols refer to relevé groups, numbered as in the dendrogram of Fig. 4 (see also Tab. 1).

4. Always at tree base, most frequently (72%) North-exposed, on *Robinia*, *Tilia*, *Platanus* and *Aesculus*, never on *Quercus*.

The results of the ordination of relevés are shown in Fig. 6. The relevés are arranged in the form of a horse-shoe. The sequence of the centroids of the relevé groups along the horse-shoe is: 1, 2, 5, 4, 3. An ecological interpretation of the ordination's results has been attempted on the basis of the indicator values (tolerance ranges) assigned to the various species by Wirth (1980). The relative frequencies in the classes of pH, photophytism, nitrophytism and hygrophytism, calculated over the total occurrences in each relevé group, are in Tab. 2. The results are further visualized in Fig. 7 (a-d), that reports the frequency distributions of the classes of ecological factors in each relevé group, the relevé groups being ordered

CLASSES OF ECOLOGICAL INDEXES (WIRTH, 1980)			RELEVÉ GROUP NUMBERS			
			1	2	3	4
a)						
pH	3.3		1.8	.....	.....	.....
pH	3.4-4.0		51.4	7.7	3.0	1.8
pH	4.1-4.8		85.3	56.1	26.0	20.7
pH	4.9-5.6		75.2	59.1	57.0	41.9
pH	5.7-7.0		31.2	82.3	93.0	87.0
pH	around 7.0		11.0	28.4	37.0	51.6
pH	7.1-8.5		6.4	9.2	12.0	23.0
b)						
skiophytic	A		0.9	.....	.....	.....
rather skiophytic	B		20.1	5.3	3.0	0.9
little skiophytic	C		49.5	23.8	4.0	4.6
rather photophytic	D		77.2	93.8	88.1	95.8
photophytic	E		22.0	33.8	32.6	48.3
c)						
non nitrophytic	A		64.2	43.0	23.1	16.5
little nitrophytic	B		95.4	88.4	75.2	61.7
rather nitrophytic	C		51.3	67.0	84.1	80.6
very nitrophytic	D		12.8	22.3	23.7	42.6
extremely nitrophytic	E		.....	.....	.....	1.4
d)						
extremely hygrophytic	A		4.6	0.7	.....	.....
very hygrophytic	B		41.2	7.7	2.9	.....
rather hygrophytic	C		68.8	25.3	15.8	5.9
mesophytic	D		87.1	66.9	66.3	40.5
rather xerophytic	E		35.7	86.9	86.1	94.4
very xerophytic	F		.....	23.8	31.6	58.8

Tab. 2 — Frequency distribution of occupancies in the classes of ecological indexes, in relevé groups 1-4 (see text).

according to their sequence along the horse-shoe in the ordination scatter diagram (Fig. 6). Relevé group 3 has not been taken into consideration in Fig. 7, since it contains only ten relevés, all taken in a very narrow area with particular ecological conditions (see later). The results may be briefly summarized as follows: the arrangement of the relevés in the scatter diagram of Fig. 6 reflects the following

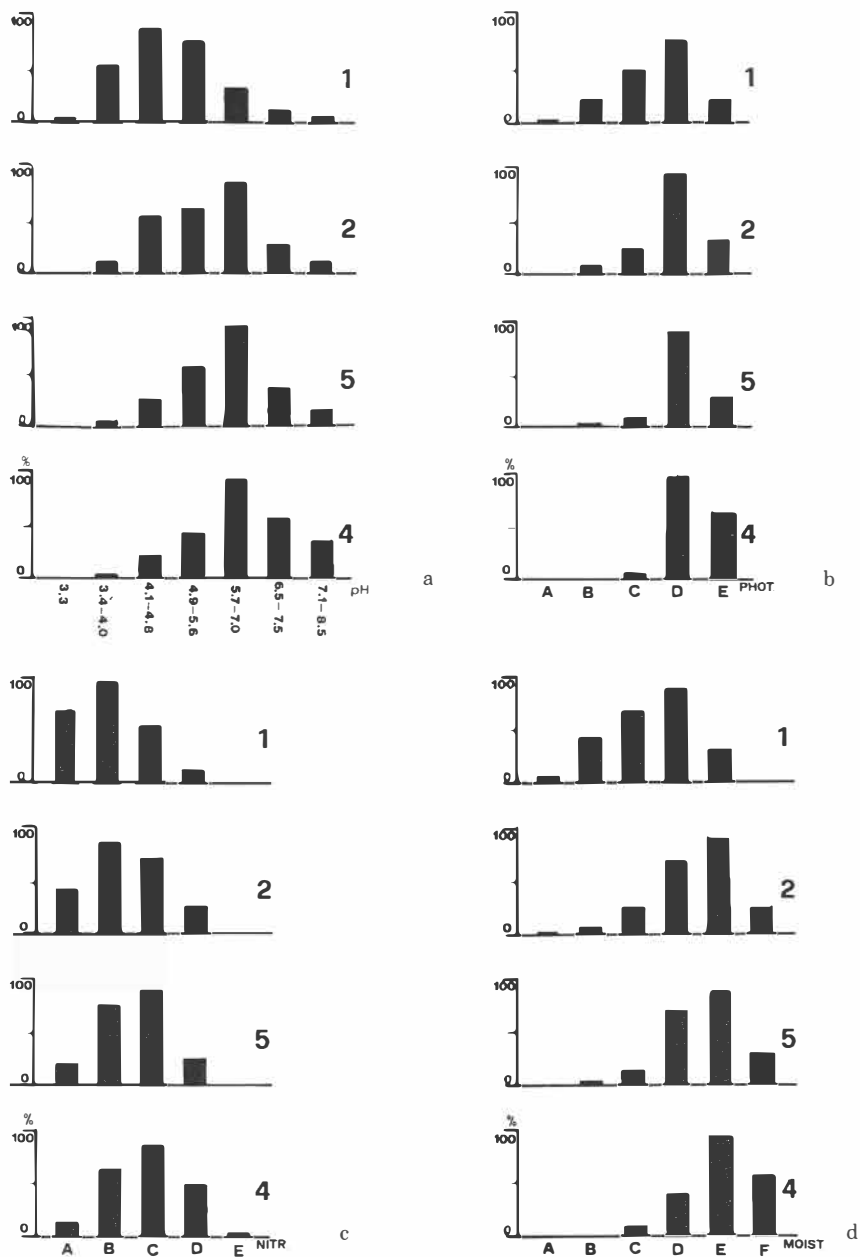


Fig. 7 — Frequency distributions of the classes of ecological factors (as in Wirth, 1980), in releve groups 1, 2, 4, 5. Numbers refer to releve groups, as in Tab. 1, capital letters to classes of ecological factors, as in Tab. 2. a) pH classes, b) photophytism classes, c) nitrophytism classes, d) hygrophytism classes.

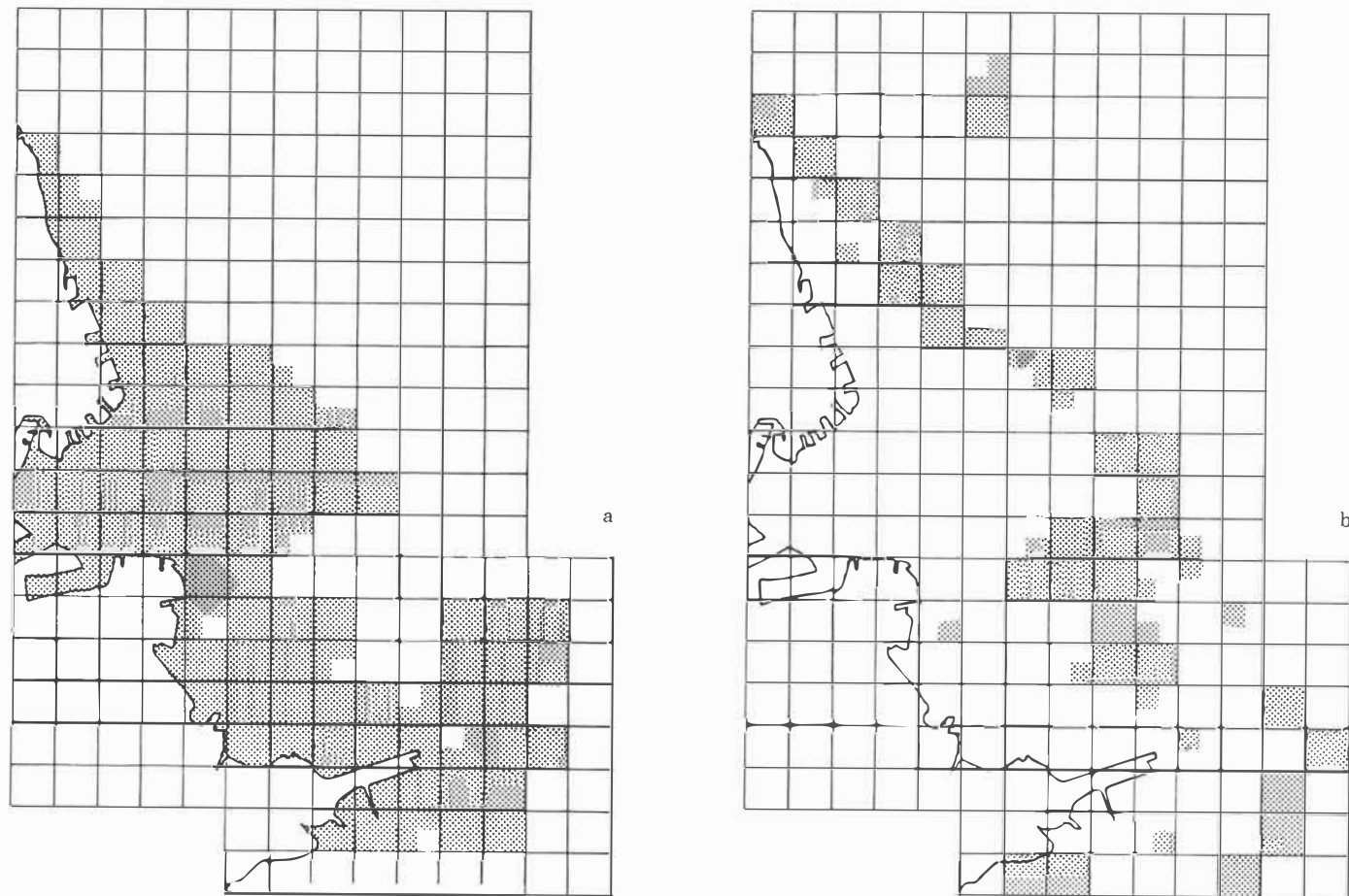


Fig. 8 — Distribution of the releve groups in the survey area. a) lichen desert, b) releves of group 5.

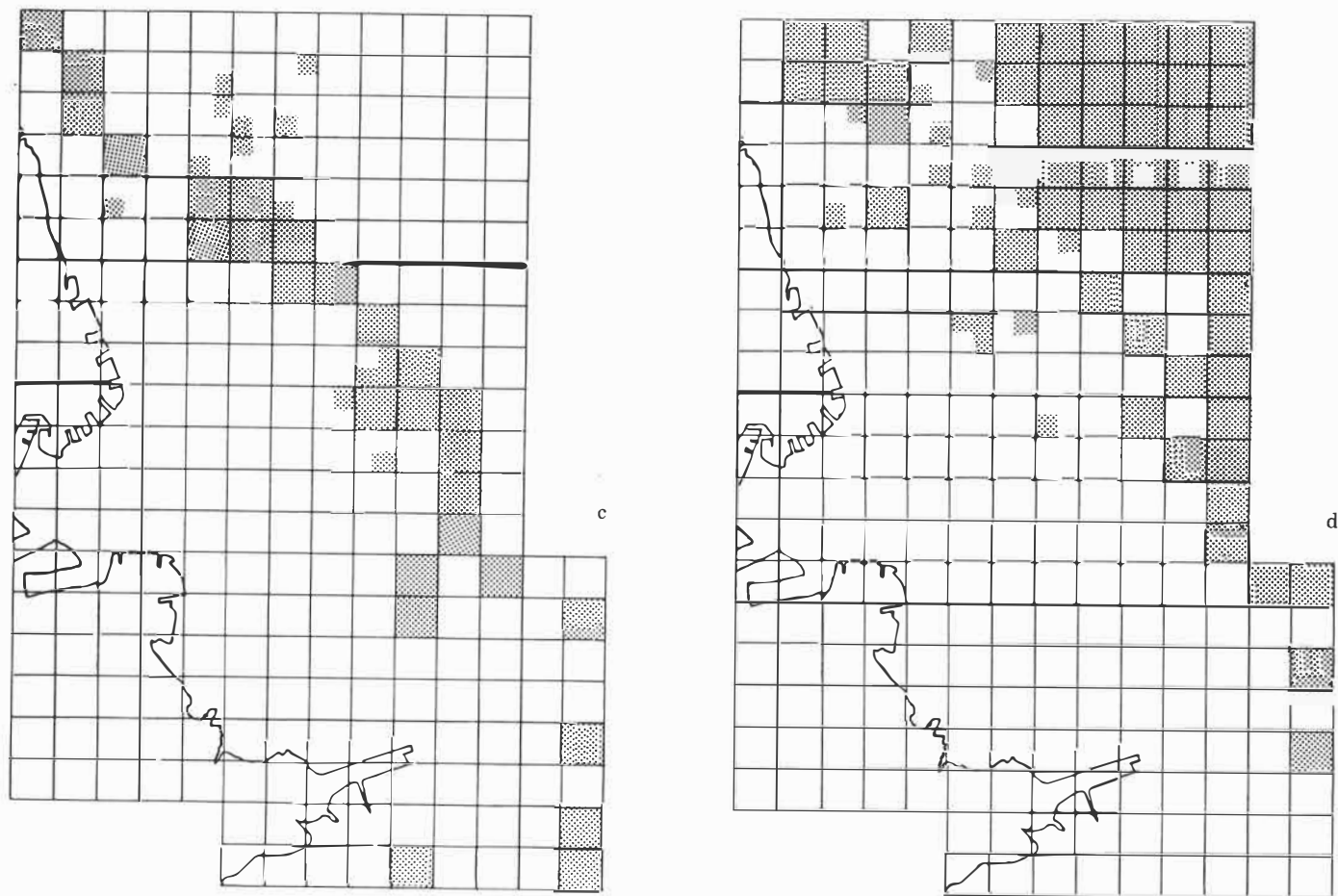


Fig. 8 — Distribution of the releve groups in the survey area. c) releves of group 4; d) releves of groups 1 and 2.

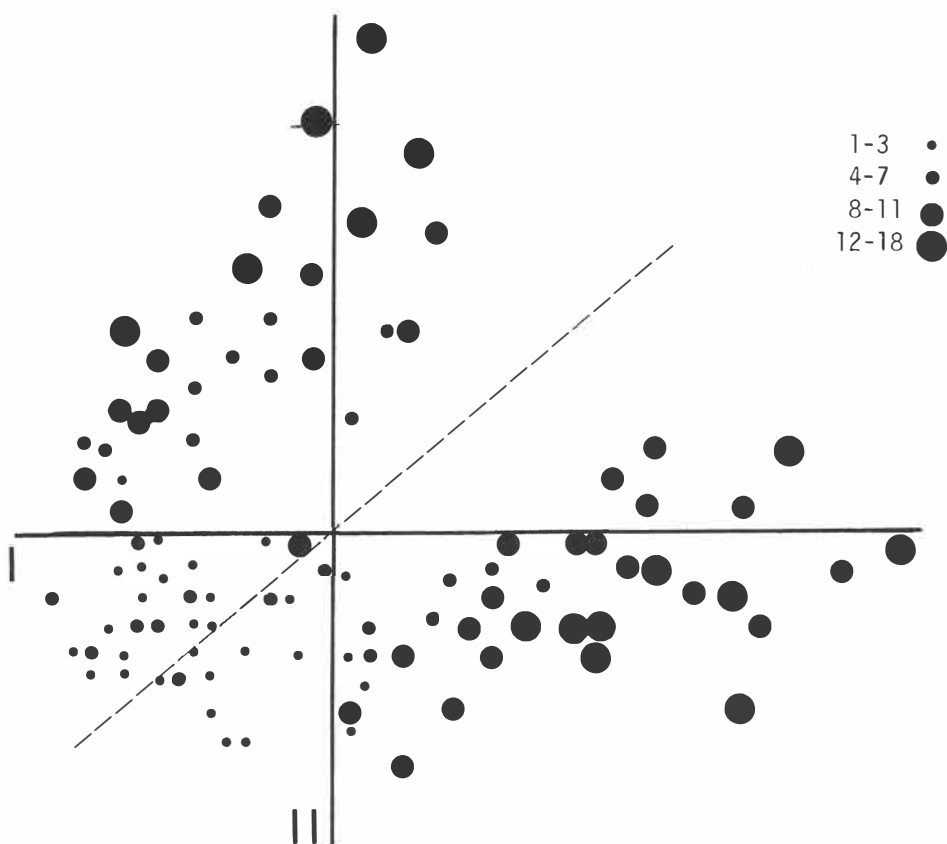


Fig. 9 — Relation between species diversity in the relevés and their arrangement in the ordination of Fig. 6. Size of dots refers to diversity classes, as in the legend.

trends (from releve group 1 to releve group 4):

- increase of neutro-basiphytic species
- increase of photophytic species
- increase of nitrophytic species
- increase of xerophytic species.

Fig. 8 (a-d) shows the distribution of the releve groups in the survey area. The relevés of groups 1 and 2 have been mapped together (Fig. 8d), since they have a very similar distribution pattern, those of releve group 3 have not been mapped, since they are all restricted to the top of the hill of S. Luigi, a rather peculiar, narrow area, very much exposed to the bora-wind. Fig. 8a shows the parts of the town where the trees are completely devoid of lichens ("lichen desert"). From Fig. 8 it is evident that the relevés of groups 5, 4, 1 and 2 have different degrees of poleophoby: less poleophobic are the relevés of group 5, followed by those of group 4, and finally by those of groups 1 and 2. Fig. 9 shows species diversity in the relevés, arranged as in

the ordination scatter diagram of Fig. 6. By rotating the first Principal Component of 45° the relevés are arranged on the new axis according to a gradient of increasing poleophoby. This gradient is paralleled by a increase of the mean number of species in the relevés, from the heavily urbanized areas to the outskirts of the town.

Analysis of pollution data

Tab. 3 reports the pollution data of the 28 deposimetric stations. The location of

ST. No.	A	B	C	D	E	F	G	H
1	1.21	0.60	0.13	0.23	0.12	0.06	0.06	0.24
2	1.16	0.25	0.09	0.17	0.08	0.04	0.07	0.19
3	1.25	0.94	0.13	0.24	0.10	0.05	0.05	0.17
4	0.94	0.54	0.09	0.19	0.08	0.04	0.03	0.15
5	1.26	0.40	0.24	0.48	0.18	0.11	0.09	0.33
6	1.78	1.75	0.11	0.26	0.13	0.06	0.05	0.19
7	0.94	0.27	0.13	0.19	0.11	0.06	0.06	0.24
8	1.01	0.40	0.15	0.18	0.10	0.05	0.15	0.30
9	1.14	0.54	0.13	0.19	0.11	0.05	0.05	0.19
10	1.05	0.80	0.11	0.22	0.10	0.05	0.04	0.17
11	1.22	0.73	0.23	0.29	0.15	0.09	0.21	0.42
12	1.28	0.73	0.25	0.33	0.16	0.10	0.17	0.40
13	1.19	0.75	0.24	0.30	0.16	0.10	0.11	0.30
14	1.53	0.97	0.38	0.42	0.23	0.16	0.48	0.87
15	1.11	0.77	0.20	0.26	0.14	0.08	0.08	0.27
16	2.70	0.94	0.58	0.81	0.48	0.36	1.08	1.76
17	1.15	0.52	0.23	0.23	0.13	0.08	0.11	0.25
18	1.13	0.39	0.18	0.21	0.13	0.08	0.07	0.26
19	1.92	0.56	0.45	0.41	0.27	0.19	0.35	0.61
20	1.39	0.73	0.19	0.26	0.14	0.08	0.08	0.26
21	1.25	1.20	0.15	0.26	0.11	0.06	0.10	0.26
22	0.88	0.77	0.12	0.19	0.13	0.05	0.05	0.22
23	1.32	0.83	0.20	0.22	0.16	0.09	0.09	0.31
24	1.80	1.02	0.46	0.52	0.30	0.21	0.30	0.76
25	1.12	0.42	0.19	0.19	0.12	0.06	0.05	0.22
26	1.14	0.65	0.15	0.24	0.12	0.06	0.06	0.22
27	1.68	1.46	0.14	0.22	0.16	0.07	0.05	0.22
28	1.11	1.02	0.11	0.21	0.10	0.05	0.03	0.16
	$(\text{g/m}^2)^{-3}$	$(\text{g/m}^2)^{-2}$	$(\text{g/m}^2)^{-1}$	$(\text{g/m}^2)^{-1}$	g/m^2	g/m^2	g/m^2	g/m^2

Tab. 3 — Results of the analyses of the 28 deposimetric stations (averages of 5 years). A) Magnesium, B) Chlorures, C) Calcium, D) Sulphates, E) Soluble substances, F) Ashes of soluble substances, G) Ashes of insoluble substances, H) Total fallout.

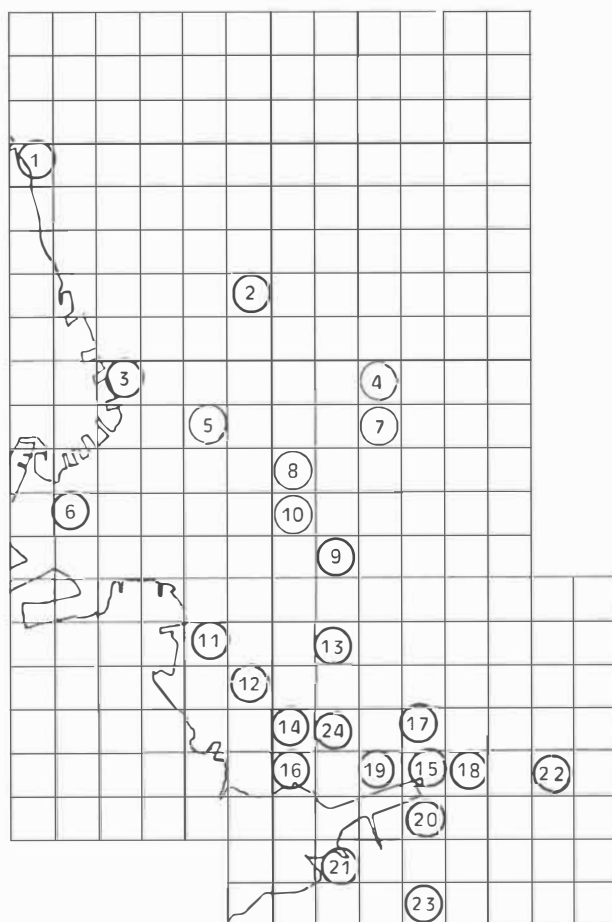


Fig. 10 — Location of the deposimetric stations within the survey area. Numbers refer to the stations, as in Tab. 3.

these stations in the survey area is shown in Fig. 10. 4 stations are outside of the map. The data of Tab. 3 have been submitted to classification and ordination. The dendrogram of the stations is shown in Fig. 11: four main groups (a-d) are formed. The ordination's results are shown in Fig. 12. The first Principal Component accounts for 75.3% of the total variance, the second for 11.9%. The four groups of stations obtained by classification are still recognizable in the ordination; the sequence of their centroids along the first Principal Component is as follows: b, c, d, a. Fig. 13 (a-g) reports the values of the variables in each stations, and the stations are arranged on the x-axis according to their projections on the first Principal Component of Fig. 12. It is evident that the first Principal Component reveals a gradient of decreasing pollution from the left side (station group b) to the right side

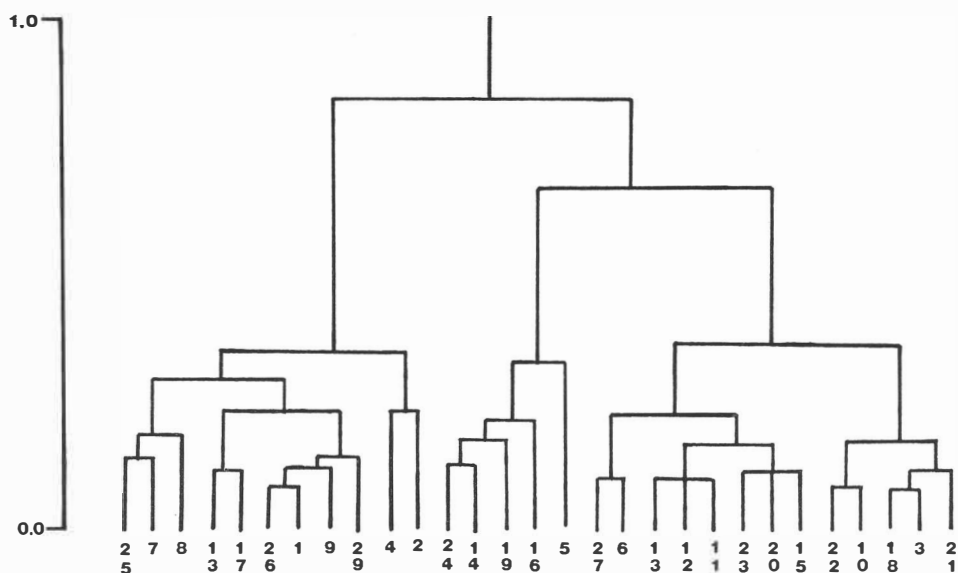


Fig. 11 — Classification of deposimetric stations on the basis of the data in Tab. 3. The stations are numbered as in Tab. 3.

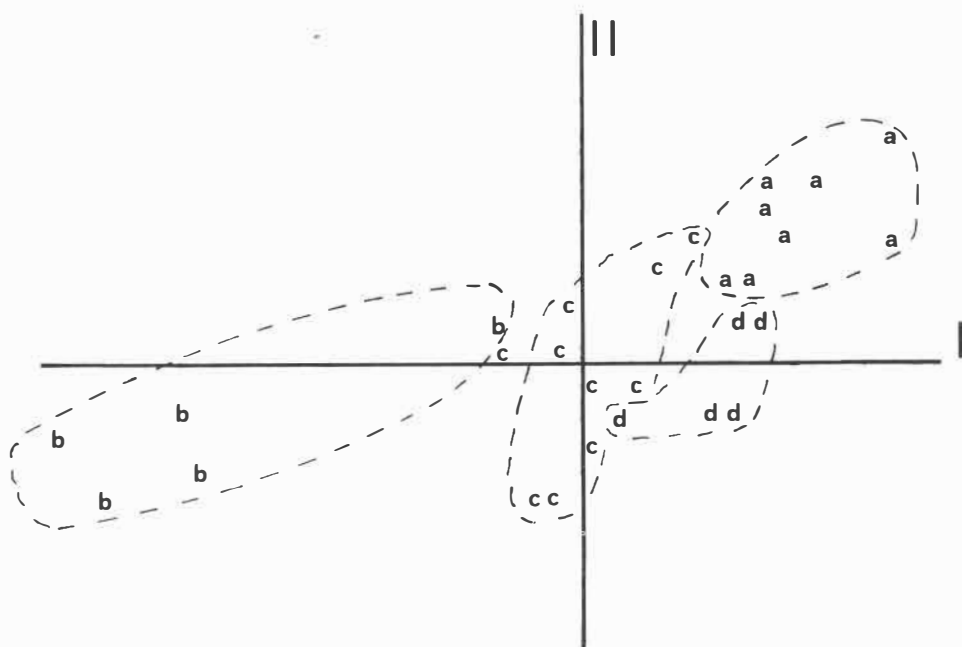


Fig. 12 — Ordination of deposimetric stations on the basis of the data in Tab. 3. Letters refer to station groups obtained by numerical classification of the same data set (see text).

(station group a). The distribution of the stations included in the four groups within the survey area is as follows:

- group a: this group includes the stations with less pollution. They are all distributed within an area roughly corresponding to the distribution area of releve group 5.
- group b: the stations included in group b have the highest pollution values. With the exception of station Nr. 5, they are all located in a narrow area in the industrial zone of Trieste.
- groups c, d: the stations in these groups have pollution values that are intermediate between those of the stations of group a and the stations of group b. They are mostly located in the lichen desert zone, between the distribution areas of the stations of groups a and b.

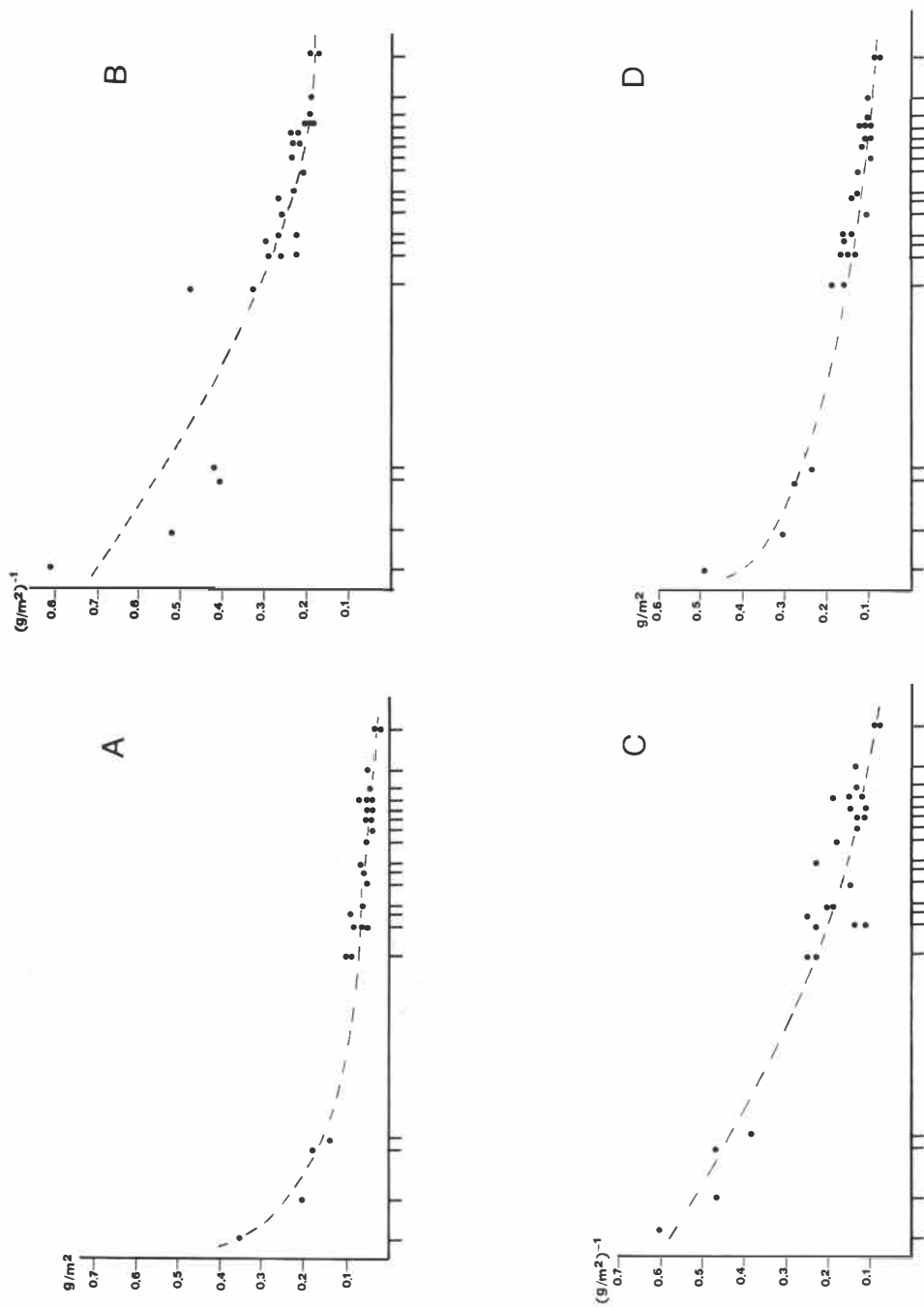
Zonation of the town and indicator species

Fig. 14 shows a subdivision of the urban area of Trieste in six zones. Such a zonation is based on the results of the analysis of both floristic and pollution data. Of the six zones, three are defined by the occurrence of a certain type of lichen vegetation (1, 2, 3), three by given range of pollution (b, c, d; in the following the pollution levels are expressed as total fallout), as follows:

- Zone b: it is the most polluted zone; it coincides with part of the industrial area of Trieste (group of deposimetric stations b). Trees are completely devoid of lichens. Mean pollution level is $0.86 \text{ g/m}^2/\text{day}$.
- Zone c: the pollution is much lower than in the previous zone (average $0.29 \text{ g/m}^2/\text{day}$): it occupies a belt surrounding zone b.
- Zone d: the pollution levels are slightly lower than those recorded in the stations of zone c (average $0.22 \text{ g/m}^2/\text{day}$). Also this zone is mostly located within the lichen desert, surrounding zone c.
- Zone 1: this zone is characterized by the prevalence of releves of group 5. Lichens are mainly present at the base of the boles. The zone includes most of the deposimetric stations of group a. The pollution level at which lichens begin to appear averages $0.20 \text{ g/m}^2/\text{day}$.
- Zone 2: this zone is characterized by the prevalence of releves of group 4. Lichens are present both at tree base and at 1.5 m on the bole. No data on air pollution are available, but this should be under $0.20 \text{ g/m}^2/\text{day}$.
- Zone 3: this zone is characterized by the prevalence of releves of groups 1 (in woody stands) or 2 (on isolated trees), more rarely releves of group 4 still occur at the S-side of isolated wayside trees. Lichens are abundant both at tree base and at 1.5 m on the boles. No pollution data are available.

It is also possible to define the zones 1, 2 and 3 by the presence of some easily recognizable species (indicator species). Fig. 15 shows the frequency distributions of selected species in the releves groups (the latter are arranged according to the projection of their centroids on the rotated first axis of Fig. 6, see also Fig. 9).

- Zone 1: the only indicator species for this zone are *Physcia adscendens*, *Physcia orbicularis* and (weakly) *Physcia aipolia* (Fig. 15a). They occur also in the



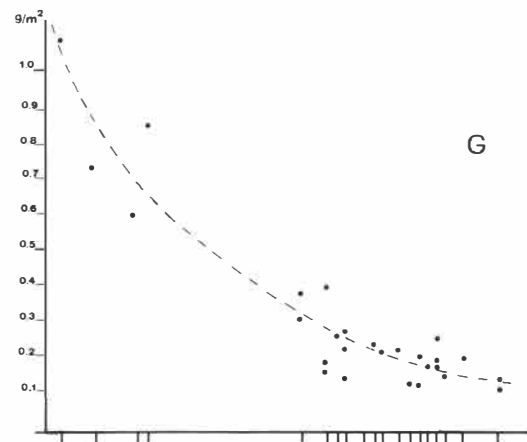
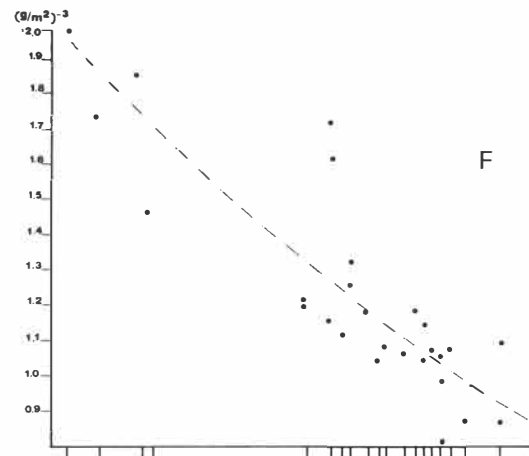
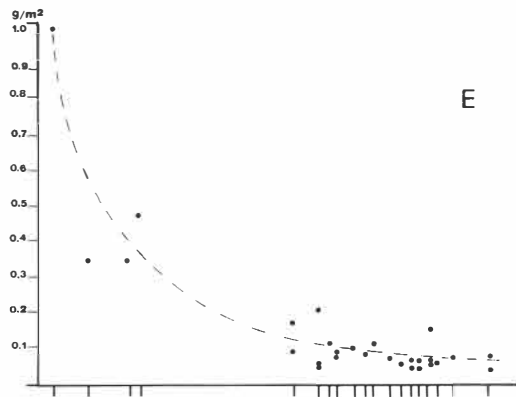


Fig. 13 —

Direct interpretation of the ordination of deposimetric stations (see Fig. 12). The x-axis reports the scores of each station on the first Principal Component in the ordination of Fig. 12; the y-axis refers to the amount of pollutants in each station. Each graph refers to a single pollutant, labelled with a capital letter, as follows: A) Soluble substances, B) Sulphates; C) Calcium, D) Ashes of soluble substances, E) Ashes of insoluble substances; F) Magnesium; G) Total fallout.

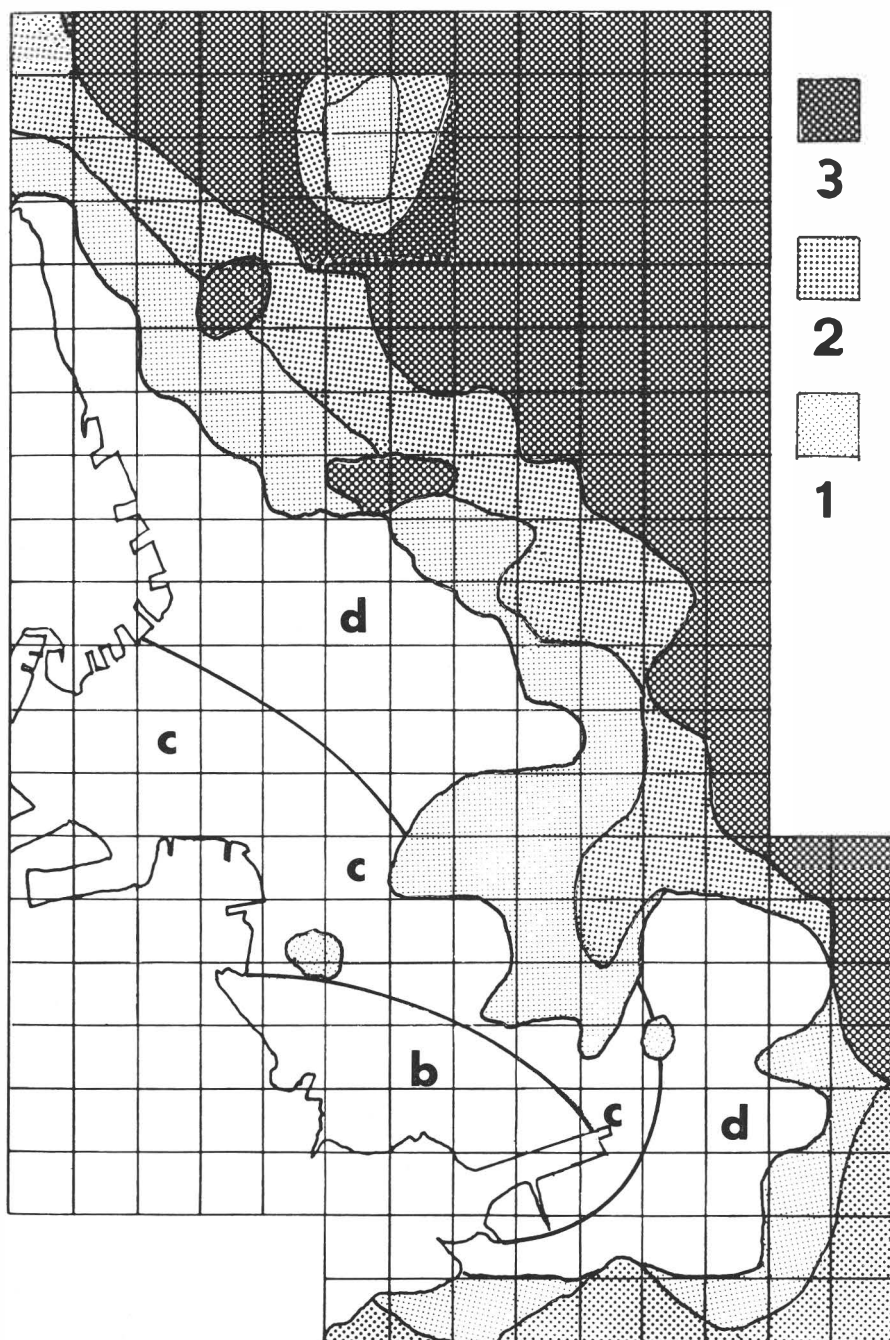


Fig. 14 — Zonation of the survey area, based both on floristic and pollution data (see text).

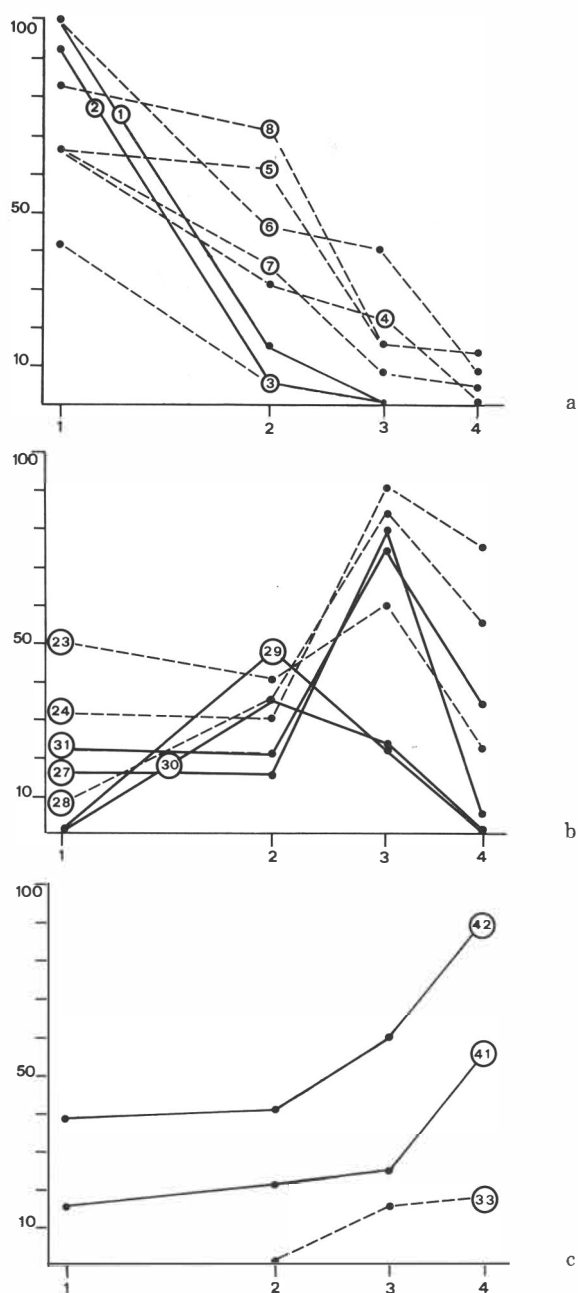


Fig. 15 — Identification of indicator species for four relevé groups. The x-axis reports the scores of the centroids of relevé groups 1, 2, 3 and 4 on the rotated first axis of the ordination of relevés based on floristic data (see Fig. 6), the y-axis refers to the frequency of each species in the relevé groups. Species are identified by circled numbers (as in Tab. 1). a) indicator species of relevé group 1; b) indicator species of relevé groups 2 and 3; c) indicator species of relevé group 4.

other zones; zone 1 is defined by their being the most abundant lichens at tree base when the trunks are completely devoid of lichens.

Zone 2: the best indicator species for zone 2 are: *Lecanora chlorotera* and *Candelaria concolor*. *Xanthoria parietina* and *Physcia biziana* may be used as indicator of this zone if present at 1.5 m on the bole of the tree. (Fig. 15b)

Zone 3: *Evernia prunastri*, *Hypogymnia physodes* and *Usnea hirta* are good indicator species for stands in light woods. Other indicator species, frequent also on isolated trees are: *Parmelia subaurifera*, *Parmelia caperata*, *Parmelia sulcata*, *Parmelia tiliacea* and *Parmelia subrudecta* (Fig. 15c).

Since the zones 1, 2 and 3 are respectively located at increasing distance from heavily urbanized areas, the indicator species may be considered as being mentioned in order of increasing poleophoby.

Discussion and Conclusions

Most authors agree that air pollution is the main factor influencing the distribution of lichens in urban areas. According to Rydzak (1969), however, the drier climate of urbanized areas should also be taken into account as another main factor influencing the distribution of lichens. In my opinion, both factors should be taken into consideration when interpreting distribution patterns of lichens around towns, and the relative importance of drought should be expected to increase with increasing aridity of the general climate. It is perhaps not a case that most of the authors that expressed themselves against Rydzak's views were from Western Europe (oceanic climate), and that Rydzak himself was working in continental Poland.

The results of the present study are difficult to interpret on the sole basis of the pollution hypothesis. From the periphery to the center of Trieste there is an increase in the frequency of xerophytic, nitrophytic and neutro-basiphytic species. If pollution alone would be the main factor affecting lichen distribution in the Trieste area, one should expect an increase in acidophytic species (secondary acidification of the bark by air pollution) towards the most polluted areas. Trieste has a rather dry climate (see Fig. 1); although direct data on the urban microclimates of Trieste are not available, another fact that characterizes the climate of Trieste as relatively dry is the extremely low frequency of *Lecanora conizaeoides* within the town. This species is the most toxitolerant lichen which occurs on trees (Laundon, 1973), and its distribution considerably enlarged in the last century, above all in Northwestern Europe (suboceanic conditions). Nimis (1986) found it abundantly in Udine, that has a more humid climate than Trieste, whereas in Trieste it was present only on two trees in the Jewish Cemetery, which were growing in a very shady site, at the N-side of a high wall. It seems that in Trieste drought could have an influence in the distribution of lichens: in the study area most of the available xerophytic epiphytes are also neutro-basiphytic (*Xanthorion*-species): they can stand the drier climate of the urbanized area, but cannot survive on acid bark. This is why towards the center they are mostly restricted to tree bases, where the pH is around 7.0

(secondary eutrophication by dust and nitrates); although they are mostly photophytic, in the urban environment they tend to be limited at the North exposed side of the trunks, where evapotranspiration is lower. At the other side, most of the acidophytic species present in the area are also rather hygrophytic (*Parmelietales*-species): they find their optimal development in the *Quercus*-woods surrounding the town, where both low pH (*Quercus* bark is normally acid) and higher air humidity are available. The acid bark of trees within the urban area is not colonized by any lichens; the reason is probably that the pH is too low for *Xanthorion*-species and air humidity is too low for *Parmelietales*-species. The explanatory model presented above should be compared with the one proposed by Nimis (1986) for the town of Udine, located less than 100 Km far from Trieste, where the climate is more humid and the distribution patterns of lichens are very different from those recorded in Trieste.

Riassunto

Viene studiata la distribuzione dei licheni nell'area urbana di Trieste. Lo studio si basa su 213 rilievi fitosociologici di vegetazione lichenica epifita, e sui dati di inquinamento relativi a 28 stazioni deposimetriche. I risultati della classificazione numerica dei rilievi permettono di individuare quattro tipi vegetazionali principali, caratterizzati da diversi gradi di poleofobia. L'ecologia dei quattro gruppi di rilievi è stata studiata sulla base sia di misure dirette di pH, sia degli indici di tolleranza a pH, luce, aridità e nitrati, attribuiti a ciascuna specie da Wirth (1980). Dalla periferia al centro della città si ha una diminuzione del numero assoluto di specie, ed un aumento della frequenza relativa di specie xerofitiche, neutrobasifitiche, fotofitiche e nitrofitiche. Tali risultati non sembrano interpretabili considerando il solo inquinamento atmosferico come fattore ecologico principale. La maggiore aridità nell'ambito delle zone fortemente urbanizzate sembra essere un fattore limitante di notevole importanza per la crescita dei licheni. I risultati permettono di suddividere l'area urbana di Trieste in sei zone: tre sono definite dalla presenza di determinate specie di licheni, le rimanenti vengono delimitate in base a dati di inquinamento.

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Authors' address:

Prof. Dr. Pier Luigi Nimis
 Dipartimento di Biologia
 Sez. Geobotanica ed Ecologia
 Cas. Università
 I 34100 Trieste

CONTRIBUTI ALLE CONOSCENZE FLORISTICHE SUI LICHENI D'ITALIA III. FLORULA LICHENICA DELLE ISOLE TREMITI

Pier Luigi NIMIS

Parole chiave: Isole Tremiti, Licheni, Flora.

Riassunto. 123 specie di licheni vengono riportate per l'Arcipelago delle Tremiti. Di queste, 68 sono epi-endolitiche su calcare, 40 sono epifite, 15 sono epigee. La relativa povertà della florula lichenica delle Tremiti è dovuta soprattutto al forte apporto di nitrati da parte di colonie di uccelli marini, ed alla scarsità di boschi naturali con un grado sufficiente di umidità atmosferica. Particolarmente interessanti sono i pochi frammenti di vegetazione lichenica epifita nell'isola di S. Domino, che ospitano una serie di specie ad affinità occidentali (subatlantiche).

Introduzione ed Area di Studio

Recentemente, nel preparare cartine di distribuzione in Italia di alcuni generi di macrolicheni, ho avuto l'occasione di rendermi conto come nella maggior parte degli erbari italiani vi sia una seria lacuna di campioni raccolti lungo il litorale adriatico, che risulta essere forse la parte meno studiata d'Italia dal punto di vista lichenologico. Il presente lavoro vuole costituire un primo contributo allo studio della flora lichenica dell'Italia Adriatica. Esso è il terzo di una serie (Nimis, 1985a, 1985b) che si propone di rendere note florule licheniche il più possibile complete di aree ristrette e relativamente omogenee dal punto di vista climatico e vegetazionale.

L'area di studio comprende le tre principali isole dell'Arcipelago delle Tremiti: S. Domino (1.98 kmq), Capraia (0.51 kmq) e S. Nicola (0.48 kmq), per un'estensione totale di 2.97 Kmq. Le Isole Tremiti sono situate a settentrione del Gargano, a circa 12.5 miglia marine dalla costa adriatica (Torre Miletto). I principali aspetti geomorfologici delle tre isole possono venir riassunti come segue (dati da: De Marco et al., 1984):

S. Domino: prevalgono i calcari organogeni dell'Eocene inferiore e medio; localmente (Faro) affiorano dolomie calcaree del Pliocene superiore e dell'Eocene inferiore. L'isola è la maggiormente elevata: 119 m al Colle del Romito.

Capraia: prevalgono dolomie e calcari dolomitizzati dell'Eocene inferiore. L'isola ha l'aspetto di un piano uniformemente inclinato verso SE, con due picchi

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principali ai due estremi, il più alto dei quali raggiunge i 56 m.

S. Domino: è costituita da un pianoro di dolomie e calcari miocenici che affiorano lungo le pareti subverticali che costituiscono i margini del pianoro. Il punto più alto è sito a 75 m.

S. Domino e S. Nicola ospitano degli insediamenti, Caprara è disabitata e gli unici edifici sono una casa abbandonata ed un faro. Colonie di uccelli marini (Diomedee) sono abbondantissime soprattutto presso le coste a falesia, ed assicurano un continuo apporto di nitrati.

Il clima delle tre isole è stato studiato in dettaglio da De Marco et al. (1984): la precipitazione media annua va da un minimo di 587.1 mm a S. Nicola, ad un massimo di 615.5 mm a S. Domino, con un regime pluviometrico di tipo IV b (eumediterraneo) ed un indice termico di 20.99 (mediterraneo caldo). Il clima presenta scarsa piovosità media annuale, inverno mite od assente, assenza di uno spiccato periodo di aridità estiva, elevata umidità relativa in estate. Un dato interessante è che le precipitazioni di Agosto a S. Domino sono quasi il doppio che nelle altre due isole (14.2 mm).

La vegetazione prevalente è una macchia a lentisco, frequente su tutte le isole, spesso degradata a prateria aperta, soprattutto a S. Nicola e Caprara. S. Domino ospita gli unici boschi, dominati da *Pinus halepensis*, e, limitatamente alla parte esposta a settentrione, da *Quercus ilex*. Per maggiori dettagli si veda lo studio e la carta vegetazionale di De Marco et al. (1984).

Dati e metodi

I campioni raccolti sono stati identificati presso il Dipartimento di Biologia dell'Università di Trieste. Per tutte le citazioni della lista floristica esiste almeno un esemplare depositato presso l'Erbario Nimis (TSB). Dette citazioni sono inoltre state inserite nella Banca Dati sui Licheni d'Italia (Nimis, 1985 c). Ad ogni specie viene assegnata una breve nota sull'ambiente in cui cresce e sulla sua frequenza. Le diagnosi corologiche sono quelle di Wirth (1980). Nella lista floristica l'inquadramento sistematico è quello recentemente proposto da Henssen & Jahns (1974), con alcune modifiche tratte da Poelt & Vezda (1981). La nomenclatura segue quando possibile Wirth (1980); nei pochi casi in cui ciò non avviene essa segue Poelt (1969) e Poelt & Vezda (1977, 1981).

Lista floristica

COLLEMATACEAE

Collema cristatum (L.) Wigg.

Poco frequente su calcari suborizzontali esposti al sole senza notevole accumulo di nitrati. S. Nicola, S. Domino. Bor-med.

Collema polycarpon Hoffm.

Come il precedente, ma un po' più comune. Su tutte le isole. Arkt - med.

Collema tenax (Sw.) Ach. em. Degel.

Molto comune su tutte le isole, al suolo sia nell'ambito di vegetazione naturale

aperta, sia lungo i sentieri in terra battuta. Arkt - med.

PARMELIACEAE

Evernia prunastri (L.) Ach.

Rinvenuta una sola volta a S. Domino, su rametti di *Juniperus*. Bor - med.

Hypogymnia physodes (L.) Nyl.

Alla base di *Pinus halepensis* nell'Isola di S. Domino, estremamente rara, Arkt - med.

Parmelia sulcata Tayl.

Come la precedente, rinvenuta una sola volta. Arkt - med.

LECANORACEAE

Lecania albariella (Nyl.) Muell. Arg.

Su pareti subverticali calcaree esposte a mezzogiorno. S. Nicola, Caprara, Mieur - med.

Lecania cyrtella (Ach.) Th. Fr.

Sulla scorza di *Ficus*, lungo una strada a S. Domino, poco frequente. S' bor - med.

Lecania erysibe (Ach.) Mudd

Su calcari esposti al sole con forte accumulo di nitrati, anche su muretti di asbesto-cemento, piuttosto comune. Arkt - med.

Lecania spadicea (Flot.) - Zahlbr.

Frequente su tutte le isole su calcari, soprattutto pareti subverticali. Med.

Lecania sp.

Si tratta di una *Lecania* del gruppo di *L. erysibe* s.l., che cresce su calcari sottoposti agli spruzzi salati. Il materiale raccolto (S. Domino) non aveva spore mature.

Lecanora albescens (Hoffm.) Flk.

Su calcari esposti al sole con accumulo di nitrati, comune su tutte le isole. Una forma a tallo particolarmente ben sviluppato è frequente sui calcari sottoposti a spruzzi salati. Bor - med.

Lecanora atra (Huds.) Choisy var. **calcareae** Jatta

Poco frequente su tutte le isole su calcari soprattutto esposti a settentrione. S' bor - med.

Lecanora campestris (Schaer.) Hue

Rinvenuta una sola volta a S. Domino su calcari in ombra, lontano dalla costa. Bor - med.

Lecanora dispersa (Pers.) Sommerf.

Su muretti di asbesto - cemento e manufatti di pietra calcarea presso gli abitati, poco frequente. S. Domino, S. Nicola. Chiaramente diversa da *L. albescens* (soprattutto dalla forma litorale di quest'ultima), di cui è a volte considerata una semplice forma.

Lecanora chlarotera Nyl.

Abbastanza frequente su tutte le isole su alberi lungo le strade. S' bor med.

Lecanora crenulata (Dicks.) Hook.

Alla sommità di blocchi calcarei, poco frequente. S. Domino (Arkt) - bor - med.

Lecanora hageni (Ach.) Ach.

Rara su calcari con accumulo di nitrati ed alla base di alberi isolati (accumulo di polvere calcarea). S. Nicola. Bor-med.

Lecanora laevis Poelt

Frequente su tutte le isole, sia su alberi coltivati che su *Pistacia* nella macchia litoranea. S'mieur - med.

Lecanora muralis (Schreb.) Rabenh. var. **versicolor**

Su superfici calcaree subverticali. S. Nicola, S. Domino. S'bor - med (?).

Lecanora saligna (Schrad.) Zahlbr.

Molto frequente a S. Domino sulla scorza e sul legno di *Pinus halepensis*. Meno frequente su leccio e *Pistacia*. Bor-smed.

Lecanora sulphurea (Hoffm.) Ach.

Piuttosto rara su pareti subverticali calcaree in tutte le isole, quasi sempre accompagnata da *Lecanora atra*. S'bor - mieur - med. (mo).

Solenopsora bagliettoana C. Tav.

Su calcari al sole, senza eccessivo accumulo di nitrati. Med.

Solenopsora candicans (Dicks.) Stein.

Su calcari. S. Nicola e Caprara, piuttosto rara. S'mieur - med.

Solenopsora liparina (Nyl.) Zahlbr.

Su calcari al sole, S. Nicola. Med.

Squamarina cartilaginea (With.) P. James

Al suolo in vegetazione naturale aperta, più comune a S. Domino e a Caprara. Tutti i campioni raccolti appartengono alla varietà tipica (medulla P+ giallo). Mieur. subatl - med.

ASPICILIACEAE

Aspicilia calcarea (L.) Mudd

Comune su tutte le isole alla sommità di blocchi calcarei esposti al sole. Bor-med.

Aspicilia contorta (Hoffm.) Krempelh.

Come la precedente, ma meno frequente e maggiormente nitrofitica; anche su pietre al suolo. Bor - med.

Aspicilia radiosa (Hoffm.) Schaer.

Rinvenuta una sola volta a S. Nicola. S'bor - med.

LECIDEACEAE

Bacidia fallax (Koerb.) Lett.

Su rametti di *Fillirea* a S. Domino.

Catillaria lenticularis (Ach.) Th. Fr.

Comune su calcari in ombra su tutte le isole, particolarmente frequente a S. Domino. S'bor- med.

Catillaria nigroclavata (Nyl.) Schul.

Rara a S. Domino su *Juniperus* presso la costa. Mieur. subatl - med.

Lecidea immersa (Hoffm.) Ach.

Rinvenuta due volte a S. Domino su calcari con poco accumulo di nitrati nell'ambito della pineta. Mieur - med.

Lecidea monticola (Ach.) Schaer.

Abbastanza frequente su tutte le isole, soprattutto su piccole pietre calcaree al suolo. Arkt - med.

Lecidella elaeochroma (Ach.) Haszl.

Non frequente a S. Domino a S. Nicola, soprattutto su alberi coltivati o lungo le strade. Bor - med.

Psora decipiens (Hedw.) Hoffm.

Su suolo calcareo in vegetazione aperta su tutte le isole, più rara a S. Domino. Arkt - med, subko.

Psora lurida (With.) DC.

Rinvenuta una sola volta in una fessura di roccia calcarea con accumulo di terra a Caprara. Bor-med.

Pyrhospora quernei (Dicks.) Koerb.

Molto abbondante, e spesso anche con apoteci, nella pineta della parte settentrionale di S. Domino, su *Pinus halepensis*, *Quercus ilex* ed arbusti. Mieur (atl) - med.

Scoliciosporum umbrinum (Ach.) Arn.

Su *Pinus halepensis* a S. Domino, poco frequente. Bor-med.

Toninia aromatica (Sm.) Massal.

Al suolo a Caprara e S. Nicola, abbastanza frequente. S'bor - med.

Toninia coeruleonigricans (Lightf.) Th. Fr.

Come la precedente, ma molto meno frequente; rinvenuta anche a S. Domino. Bor-med.

CANDELARIACEAE

Candelariella aurella (Hoffm.) Zahlbr.

Comune su tutte le isole alla sommità di blocchi calcarei esposti al sole, con accumulo di nitrati. Arkt - med.

Candelariella medians (Nyl.) A.L. Sm.

Rinvenuta una sola volta a S. Nicola, assieme alla precedente. S' mieur - med.

CLADONIACEAE

Cladonia convoluta (Lam.) P. Cout.

Molto frequente su tutte le isole al suolo in vegetazione aperta S'mieur. subko-

med.

Cladonia furcata (Huds.) Schrad. subsp. **subrangiformis** (Sandst.) Pisut
Come la precedente, cui spesso è associata; Mieur - med.

Cladonia pocillum (Ach.) O.J. Rich.

Come le precedenti, ma meno frequente. Arkt - smed.mo (?).

Cladonia pyxidata (L.) Fr.

Sia al suolo che su muschi su calcare, o alla base di alberi, per lo più in stazioni poco soleggiate, abbastanza frequente soprattutto a S. Domino. Arkt - med.

Cladonia rangiformis Hoffm.

Come *Cladonia convoluta*, con cui è quasi sempre associata. S'bor - med.

RAMALINACEAE

Ramalina canariensis Steiner

Presente solo a S. Domino, su rametti a tronco di *Pinus* ed arbusti nella parte settentrionale dell'Isola. Med.

ACAROSPORACEAE

Sarcogyne pruinosa (Sm.) Mudd

Rinvenuta una sola volta a S. Domino, su muretto di asbesto - cemento. Arkt - med.

PLACYNTHIACEAE

Placynthium nigrum (Huds.) S. Gray

Poco frequente su calcari in ombra, un po' più comune nella pineta di S. Domino. Bor med.

TELOSCHISTACEAE

Caloplaca alociza (Massal.) Mig.

Abbastanza frequente su tutte le isole su calcare. Mieur - med.

Caloplaca aurantia (Pers.) Hellb.

Frequentissima su tutte le isole, su calcari con forte accumulo di nitrati, soprattutto superfici suborizzontali. S' mieur - med.

Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr.

Rinvenuta una sola volta su *Ficus* a S. Domino. Bor - med.

Caloplaca chalybaea (Fr.) Muell. Arg.

Su tutte le isole, ma poco frequente, Mieur - med.

Caloplaca citrina (Hoffm.) Th. Fr.

Molto frequente su tutte le isole dove si abbia forte accumulo di nitrati su calcare. Anche su muri e manufatti di cemento presso gli abitati. Bor - med.

Caloplaca coronata (Krempelh.) Steiner

Rinvenuta una sola volta a S. Nicola, alla sommità di un blocco calcareo. Mieur-med.

Caloplaca erythrocarpa (Pers.) Zw.

Piuttosto rara, ma presente in tutte le isole, su calcari senza forte accumulo di nitrati, ed esposti al sole. S'mieur. subatl - med.

Caloplaca ferruginea (Huds.) Th. Fr.

Rinvenuta una sola volta a S. Nicola su *Pistacia*. Bor. subatl - med.

Caloplaca flavorubescens (Huds.) Laund.

Abbastanza frequente su alberi lungo le vie, anche su *Pistacia*, a S. Domino e S. Nicola.

Caloplaca flavovirescens (Wulf.) DT. & S.

Rinvenuta una sola volta a S. Domino, su di un muro in esposizione nord. Bor - med.

Caloplaca haematites (Chaub.) Zw.

Piuttosto rara su alberi coltivati a S. Domino a S. Nicola. Smed - med.

Caloplaca heppiana (Muell. Arg.) Zahlbr.

Comunissima negli stessi ambienti di *Caloplaca aurantia*, su tutte le isole. Mieur - med.

Caloplaca holocarpa (Hoffm.) Wade

Soprattutto su alberi ed arbusti isolati, poco frequente, su tutte le isole. Forme riconducibili a *C. holocarpa* s. latiss. Sono inoltre comuni su calcari con accumulo di nitrati. Arkt - med.

Caloplaca lactea (Massal.) Zahlbr.

Comune soprattutto su pietre al suolo, su tutte le isole. Mieur - med.

Caloplaca lithophila H. Magn.

Comune su calcari con forte accumulo di nitrati, anche su muri ed altri manufatti presso gli abitati.

Caloplaca oasis (Massal.) Szat.

Piuttosto rara su calcare, parassita di *Verrucaria calciseda*, su tutte le isole. Med.

Caloplaca ochracea (Schaer.) Flag.

Su calcari in ombra nell'Isola di S. Dominio. Mieur. subatl - med (mo).

Caloplaca schaereri (Flk.) Zahlbr.

Non frequente a S. Nicola e S. Domino, su calcare. Med.

Caloplaca tenuatula (Nyl.) Zahlbr.

Abbastanza frequente su tutte le isole, parassita su specie di *Verrucaria*. S'mieur - med.

Caloplaca variabilis (Pers.) Muell. Arg.

Frequente su calcari al sole, soprattutto su pietre presso il suolo, in tutte le isole. Mieur - med.

Caloplaca velana (Massal.) Du Rietz

La specie è abbastanza frequente su calcari al sole con accumulo di nitrati su tutte le isole. Spesso però, è difficile distinguerla da talli danneggiati di *Caloplaca schaereri*. Mieur - med.

Fulgensia fulgida (Nyl.) Szat.

Su suolo calcareo in vegetazione aperta nell'isola di Caprara e S. Nicola. Med.

Fulgensia subbracteata (Nyl.) Poelt.

Come la precedente, ma più comune, su tutte le isole. S' mieiur - med.

Xanthoria calcicola Oxner

Molto comune su calcare con molto forte accumulo di nitrati. Mieur. subatl - med.

Xanthoria isidioidea (Beltr.) Reichert et Galun

Comune alla sommità di blocchi calcarei, con accumulo di nitrati, abbastanza frequentemente fertili. Med.

Xanthoria parietina (L.) Th. Fr.

Per lo più su alberi isolati lungo le vie, anche su *Pistacia* presso i margini delle falesie. Bor - med.

PHYSICIACEAE

Buellia anomala Zahlbr.

Su *Pinus halepensis* a S. Domino. La specie è nota dal Portogallo e dalla Dalmazia, sempre su *Pinus*. Nel nostro campione l'ipotecio è di color bruno molto chiaro. Med.

Buellia epipolia (Ach.) Mong.

Comune su tutte le isole, su roccia calcarea e manufatti di asbesto - cemento. Bor - med.

Buellia cf. maritima

Comune su calcari esposti agli spruzzi salati. Il tallo ha una reazione debolissima all'idrato di potassio. Med. (?).

Buellia punctata (Hoffm.) Massal.

Sulla scorza di *Pinus halepensis* a S. Domino. Bor - med.

Diploicia canescens (Dicks.) Massal.

Frequente su tutte le isole, sia su calcari in ombra (con *Dirina repanda*) che su *Pistacia*, *Pinus* e leccio. Mieur. subatl - med.

Physcia adscendens (Fr.) H. Oliv.

Su alberi lungo le strade e meno frequentemente su calcare con forte accumulo di nitrati, in tutte le isole. Bor - med.

Physcia biziana (Massal.) Zahlbr.

Rinvenuta una sola volta su *Ficus* a S. Domino. Med.

Physcia orbicularis (Neck.) Poetsch

Alla base di alberi coltivati a S. Domino e S. Nicola, poco frequente. Bor - med.

Physciopsis adglutinata (Flk.) Choisy

Alla base di alberi lungo le vie (accumulo di polvere e nitrati) a S. Nicola e S. Domino. Mieur

Physconia pulverulacea Moberg

Rinvenuta una sola volta su *Morus* a S. Domino. S'bor - smed - med (mo).

Rinodina immersa (Koerb.) Koerb.

Su calcari a S. Domino e Caprara. (Bor) - s'bor - med.

Rinodinella controversa (Massal.) Mayrh. et Poelt

Su calcari in ombra, senza eccessivo accumulo di nitrati, S. Domino, S. Nicola. Med.

PERTUSARIACEAE

Pertusaria amara (Ach.) Nyl.

Rara su leccio a S. Domino (soprattutto alla base del tronco). Bor - med.

Pertusaria heterochroa (Muell. Arg.) Erichs.

Su arbusti nella macchia alta a S. Domino e S. Nicola. Med.

Phlyctis agelaea (Ach.) Flot.

Su lecci a S. Domino. Mieur. subatl - med.

THELOTREMATACEAE

Diploschistes muscorum (Scop.) R. Sant.

Rara al suolo su tutte le isole. Inizialmente parassita su talli di Cladonie terricole. Bor - med.

GYALECTACEAE

Dimerella lutea (Dicks.) Trevis.

Rara su lecci in bosco chiuso a S. Domino. Mieur. Subatl - med (oz).

Gyalecta liguriensis (Vezda) Vezda

Esclusivamente su vecchi lecci in bosco chiuso a S. Domino. Med (?).

PYRENULALES

Porina linearis (Leight.) Zahlbr.

Frequente su calcari in ombra, in tutte le isole. Mieur - med.

Porina oleriana (Massal.) Lett.

Su calcari in ombra a S. Domino. Med (?).

Pyrenula macrospora (Degel.) Coppins & P. James.

Rara su lecci a S. Domino. Med. (?).

VERRUCARIACEAE

Catopyrenium lachneum (Scop.) R. Sant.

Comune su terra calcarea, soprattutto a S. Nicola. Bor-med.

Thelidium littorale (Leight.) Keissl.

Su calcari periodicamente sommersi dall'acqua marina. Raccolto a Caprara, ma probabilmente comune su tutte le isole.

Verrucaria calciseda DC.

Comune su calcare senza eccessivo accumulo di nitrati, in tutte le isole. Mieur - med.

Verrucaria cyanea Massal.

Su pareti subverticali calcaree esposte a settentrione, a S. Nicola e S. Domino. Bor - med. mo.

Verrucaria macrostoma Duf. & DC.

Soprattutto su muri e manufatti di cemento, a S. Domino e S. Nicola. Mieur - med.

Verrucaria muralis Ach.

Su piccole pietre al suolo e su manufatti di cemento, in tutte le isole. (Arkt) - bor - med.

Verrucaria nigrescens Pers. s.l.

Comunissima su calcari con forte accumulo di nitrati, anche su manufatti di cemento. Presso i margini delle falesie è comune una forma a tallo particolarmente spesso, delimitato da una linea più scura. Bor - med.

Verrucaria parmigera Steiner

Come *Verrucaria calciseda*, in tutte le isole. Mieur - med.

Verrucaria sphinctrinella Zsch.

Su calcari in ombra, su tutte le isole; particolarmente frequente nelle pinete di S. Domino. S'mieur - med.

Verrucaria viridula (Schrad.) Ach.

Su un muro di asbesto - cemento a S. Nicola. Mieur - med.

OPEGRAPHACEAE

Enterographa crassa (DC.) Fee.

A S. Domino su lecci in bosco chiuso, rara. Mieur. subatl - med.

Lecanactis patellarioides (Nyl.) Vain.

Su lecci e pini nella parte settentrionale dell'Isola di S. Domino. Mieur. subatl - med.

Opegrapha atra Pers.

Frequente su arbusti nella macchia alta, in tutte le isole. S'bor - med.

Opegrapha grumulosa Duf.

Comune su pareti verticali calcaree esposte a settentrione, quasi sempre associata a *Dirina repanda*.

Opegrapha lichenoides Pers.

Su *Pistacia* nella macchia alta a S. Domino. S'bor - med.

Opegrapha persoonii (Ach.) Chevall.

Rinvenuta una sola volta a S. Domino, parassita su una *Verrucaria*. Mieur - med.

Opegrapha saxatilis DC.

Molto comune su calcari esposti a settentrione. Mieur - med.

Opegrapha vermicellifera (Kunze) Laund.

Rara su lecci nel bosco di S. Domino. Mieur. subatl.

Schismatomma decolorans (Turn & Borr.) Clauz. & Vezda.

Su lecci in bosco nell'Isola di S. Domino. Molto più raro su *Pinus halepensis*.
Mieur. subatl - med.

Schismatomma picconianum (Bagl.) Steiner.

Rinvenuto una sola volta su *Ficus* nell'isola di S. Nicola, assieme a *Dirina ceratoniae*. Med.

ROCELLACEAE

Dirina ceratoniae Fr.

Su alberi coltivati, specialmente su *Ficus*, a S. Nicola. Med.

Dirina repanda (Fr.) Nyl.

Abbondantissima sulle falesie calcaree esposte a settentrione, sono presenti sia la ssp. tipica sia la ssp. *sorediata*. Med.

Rocella fucoides (Dicks.) Vain.

Come la precedente, con cui è spesso associata. Mieur. atl. - med.

ARTHOPYRENIACEAE

Arthopyrenia halodytes.

Su calcari periodicamente sommersi dall'acqua marina, comune su tutte le isole.
Mieur. atl - med.

STRIGULACEAE

Acrocordia conoidea (Fr.) Koerb.

Molto frequente su tutte le isole, su calcari in ombra. Mieur - med.

Discussione e conclusione

La lista floristica comprende 123 specie, di cui 68 (55.3%) sono epi-endolitiche, 40 (32.5%) epifite e 15 (12.2%) epigee. I licheni crostosi costituiscono il 78% del totale. Si tratta di una florula relativamente povera di specie, se paragonata con quella di altre aree anche di minore estensione (Nimis & Loi, 1982, 1984; Nimis, 1985a, 1985b). I motivi principali sono dati soprattutto dal forte apporto di nitrati su tutte le rocce calcaree non verticali, che determina una forte omogeneità floristica della vegetazione epilittica, e la scarsità di boschi naturali con umidità atmosferica sufficiente a mantenere una ricca vegetazione lichenica epifita.

Per i licheni epi-endolitici esistono quattro tipi principali di ambiente, occupati da diversi gruppi di specie:

1) Falesie subverticali esposte a Nord: sono caratterizzate dalla dominanza di tre specie: *Rocella fucoides*, *Dirina repanda*, *Opegrapha grumulosa*, cui spesso si associano altre specie sciafile relativamente poco nitrotolleranti quali *Acrocordia conoidea*, *Porina linearis*, *Porina oleriana*, *Opegrapha saxicola*. Prevalgono in ogni caso i licheni a *Trentepohlia*. Le falesie esposte a mezzogiorno sono quasi completamente prive di vegetazione lichenica.

2) Calcarei suborizzontali presso le falesie: qui l'accumulo di nitrati è massimo ed il paesaggio vegetale è dominato dal colore arancione di *Xanthoria calcicola*, *Xanthoria isidiodea*, *Caloplaca aurantia* e *Caloplaca heppiana*, cui si associano frequentemente altre specie nitrofitiche più piccole quali *Lecanora albescens*, *Verrucaria nigrescens*, *Aspicilia contorta*, *Candelariella aurella*, *Buellia epipolia* etc. Quasi tutte queste specie sono frequenti anche su manufatti in asbesto-cemento presso gli abitati. Dove l'apporto di nitrati è minore prevalgono invece *Aspicilia calcarea*, *Caloplaca erhytrocarpa*, *Verrucaria calciseda*, *Verrucaria parmigera* e *Solenopsora candicans*.

3) Calcarei suborizzontali in ombra. Particolarmente frequenti a S. Domino (vegetazione boschiva), sono colonizzati soprattutto da *Verrucaria sphinctrinella*, cui si associano altre specie piuttosto sciafile come *Catillaria lenticularis*, *Acrocordia conoidea*, *Porina linearis*.

4) I calcari sommersi ospitano due specie di licheni alofili: *Arthopyrenia halodytes* e *Thelidium littorale*, quelli particolarmente sottoposti a spruzzi salati *Buellia maritima* ed una *Lecania* che non mi è stato possibile identificare con certezza.

La vegetazione lichenica epifita è molto scarsamente sviluppata e presenta due tipi di ambiente principali:

1) Alberi isolati lungo le vie e presso gli abitati, con un relativamente alto apporto di nitrati e di polvere calcarea sul tronco. Questi ospitano una vegetazione riconducibile allo *Xanthorion parietinae*, dominata da *Xanthoria parietina*, *Lecanora chlorotera*, *Lecidella elaeochroma*, quasi mai presenti con alta copertura. Queste specie si rinvencono sporadicamente anche su rametti di lentisco presso i bordi delle falesie (accumulo di nitrati), dove però è più frequente *Lecanora laevis*.

2) Alberi di *Pinus halepensis* e di *Quercus ilex*, limitatamente ad una ristretta porzione dell'Isola di S. Domino, in esposizione Nord verso i 90-100 m. Si tratta dell'unica area che ospiti una florula lichenica epifita relativamente ben sviluppata e con specie decisamente interessanti. Il primo fatto che colpisce l'osservatore è la quasi totale assenza dei più comuni macrolicheni (*Ramalina*, *Parmelia*) che normalmente ci si aspetterebbe di trovare in un ambiente del genere. L'unica eccezione è data da *Ramalina canariensis*, che è localmente frequente. I licheni crostosi sono invece rappresentati da un elevato numero di specie tra cui le più interessanti sono una serie di specie a *Trentepohlia* quali *Gyalecta liguriensis*, *Schismatomma decolorans*, *Enterographa crassa*, *Dimerella lutea*, *Opegrapha vermifera*, *Lecanactis patellarioides*, *Pyrenula macrospora*. Tali specie sono presenti sia su pino che su leccio, ma molto più frequenti su quest'ultimo. La sola specie più frequente su pino è *Pyrrhospora quernei*, una specie normalmente presente allo stato sterile, che alle Tremiti possiede invece spesso apotecii. Sono tutte specie a distribuzione occidentale in Europa (specie subatlantiche), ad affinità subtropicale, che indicano una relativamente elevata umidità atmosferica, e rappresentano probabilmente gli ultimi relitti di una vegetazione epifita che dovrebbe essere stata assai più ricca prima della degradazione dei boschi con leccio da parte dell'azione antropica.

I licheni epigei si ripartiscono in due gruppi principali:

1) Nell'ambito di vegetazione erbacea fortemente degradata prevalgono licheni crostosi quali *Fulgensia subbracteata*, *Fulgensia fulgida*, *Toninia aromatica*, *Psora decipiens*, *Toninia coeruleonigricans*, *Collema tenax* e *Catopyrenium lachneum*.

2) Nell'ambito della macchia alta, soprattutto nelle schiarite prevalgono licheni fruticosi appartenenti al genere *Cladonia*: *Cladonia convoluta*, *Cladonia rangiformis*, *Cladonia furcata* subsp. *subrangiformis*.

Dal punto di vista fitogeografico, con la notevole eccezione delle specie epifite subatlantiche o mediterraneo-atlantiche citate sopra, prevalgono le specie ad ampia distribuzione, dalla zona artica o boreale a quella mediterranea: la ragione è dovuta alla netta prevalenza di specie fortemente nitrofitiche. Il contingente mediterraneo propriamente detto è rappresentato da 19 specie (15.5% del totale) e cioè *Lecania spadicea*, *Lecanora laevis*, le tre specie di *Solenopsora*, *Ramalina canariensis*, *Caloplaca schaereri*, *Fulgensia fulgida*, *Xanthoria isidioidea*, *Buellia anomala*, *Physcia biziana*, *Rinodinella controversa*, *Pertusaria heterochroa*, *Porina oleriana*, *Schismatomma picconianum*, *Dirina ceratoniae*. Quasi tutte sono assenti dove si hanno forti accumuli di nitrati.

Per quel che riguarda i licheni epilittici ed epigei non esistono sostanziali differenze tra le florule delle tre isole studiate, mentre l'unica differenza rilevante riguarda i licheni epifiti, che sono molto più abbondanti nell'Isola di S. Domino.

Abstract: 123 species of lichens are reported for the Tremiti Islands, in the Southern Adriatic Sea. 68 species are epilithic, 40 epiphytic and 15 epigeic. The relative poorness of the lichen flora is due to two main facts: 1) strong accumulation of nitrates throughout the islands by maritime birds, 2) absence of extensive woody stands with a rich epiphytic vegetation. Of particular interest are the few remnants of a wood dominated by *Quercus ilex* in the isle of S. Domino, which acts as a refuge for a number of subatlantic or mediterranean - atlantic epiphytic species.

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Author's address:

Prof. Dr. Pier Luigi Nimis
Dipartimento di Biologia
Sezione Geobotanica ed Ecologia
Cas. Università
I 34100 TRIESTE

PRELIMINARY NOTES ON THE VEGETATION OF HORMUZGAN (SOUTHERN IRAN) *

MARINUCCI Carmine, LEPORATTI Maria Lucia, LATTANZI Edda.

Keywords: Iran-Flora, Vegetation.

Abstract: The authors give preliminary observations on the main features of the flora and vegetation of Hormuzgan (Southern Iran).

Introduction.

Research carried out between the months of March and April, 1983, as well as the analysis of the data available in the literature, has led us to describe and identify the principal vegetation types - defined on a structural basis - of Hormuzgan (Southern Iran).

Geomorphology

The present-day administrative district of Hormuzgan, to which the observations performed during the March-April 1983 expedition refer, lies in Southern Iran, between 25° and 28° latitude N., and 54° and 58° longitude E. from Greenwich. Its coastline faces the Hormuz Strait for a length of approximately 600 km. (Fig. 1).

A series of ridge lines parallel to the coast-line, and interspersed with large flat valleys, covers the entire area.

The elevation of the ridges is conspicuous, and it tends to increase from the coast towards the interior, where its maximum values of about 2500-3000 m above sea level are reached (Kuh-e Bibi Gilan, 2645 m.a.s.l.; Kuh-e Shab, 2680 m; Kuh-e Gerdu, 3267 m.

Geologically, the area belongs to the Zagros Mountains, a recent range whose origin can be traced to the collision between the Continental Arabian Plates and Central Iranian Plates.

The range, with a total length of about 1500 km, stretches from the Tauri Mountains in Turkey to Southern Iran, where it reaches the Hormuz Strait (Stoklin &

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Fig. 1 — Enviromental characteristics of the district of Hormuzgan (Southern Iran).

Nabavil 1973; Falcon 1974).

The emergent salt domes which occur over the entire range, are due to remarkable saline diapirism phenomena, a distinctive feature of the Zagros Mountains (Fig. 3). The domes have originated from the uplift of low-density salt masses of the infracambrian age, of considerable plasticity and subject to hydrostatic thrust, which have intruded into the overlaying sedimentary series, piercing a layer 5000 to 7000 meters in thickness and, eventually, reaching the topographical surface. (Fig. 4). (Ala 1974; Kent 1970).

"Kevir" are typical forms of the plains. They are low, broad fields, towards which a series of transient watercourses flow. These watercourses tend, during the rainy season, to turn into typical marshes. During the dry season, the considerable insolation causes the water to evaporate; the consequent deposition of the salts which were previously dissolved into water results in the formation of a saline crust, several centimeters thick.

The hydrographical features of the area include the presence of several important watercourses, which originate in the inner mountain regions, such as the Rud-i Mehran, the Rud-i Kul, the Rud-i Sirhun and the Rud-i Minab. They represent the principal collectors of a very close hydrographical network which, on the whole, shows a typical trellis trend. (Fig. 1).

Main Climatic Features

Thermometric and pluviometric data recorded at the meteorological stations of Bandar Lengeh, Queshm, Bandar Abbas, Minab and Jask, have been analyzed in order to outline the climatic features of the area.

The stations which have been studied are the only ones to be found in the region. Unfortunately, neither their small number nor their geographical positions (they are all located close to the sea shore, at an altitude never exceeding 50 meters a.s.l.), have enabled us to gain full insight of the local bioclimatic conditions and, in particular, of those of the innermost hilly and mountainous regions.

Temperature

Temperature values are given in Table 1. It may be seen that monthly maximum and minimum temperatures show analogous trends and, on the whole, are quite similar in the different stations.

Mean monthly values of the maximum temperature (M) are always greater than 23° C, whereas mean monthly values of the minimum temperature (m) are never less than 12° C. The variation of (m) is recorded in the interval 12°.4 C to 30°.6 C; these values have been recorded, respectively, in January and July at Bandar Abbas. The range of the mean monthly middle temperature (M-m) is 17°.4 (January, at Bandar Lengeh) to 43°.5 C (July, at Minab).

The annual middle temperature always exceeds 26° C; its minimum and maximum values are, respectively 26°,1 C (Bandar Lengeh) and 27°,3 C (Bandar Abbas).

Monthly thermal excursions of each station are also given in Table 1. They are

BANDAR LENGEH altitude: m. 13 Lat. 26° 35' N Long. 54° 50' W year: 1966-75						BANDAR ABBAS altitude: m. 10 Lat. 27° 13' N Long. 56° 22' W year: 1957-83						QESHM altitude: m. 31 Lat. 26° 57' N Long. 56° 15' W year: 1965-74						MINAB altitude: m. 29 Lat. 27° 08' N Long. 57° 05' W year: 1965-75						JASK altitude: m. 4 Lat. 25° 38' N Long. 57° 46' W year: 1965-75					
M	m	M-m	M _a	m _a		M	m	M-m	M _a	m _a		M	m	M-m	M _a	m _a		M	m	M-m	M _a	m _a		M	m	M-m	M _a	m _a	
JAN.	22.4	12.4	10.0	28.6	6.0	23.9	12.7	11.2	32.0	3.0	22.2	15.5	6.7	29.0	7.0	23.5	12.7	10.8	32.5	4.0	23.1	15.1	8.0	28.0	6.0				
FEB.	23.0	13.3	9.7	30.0	7.0	24.8	14.6	10.2	30.6	6.0	23.0	15.8	7.2	28.0	9.2	24.5	13.9	10.6	31.0	7.0	23.2	15.6	7.6	30.0	10.0				
MAR.	27.2	16.8	10.4	36.0	10.0	27.9	17.9	10.0	35.0	8.0	26.8	18.8	8.0	33.0	13.6	29.3	17.4	11.9	37.5	8.0	26.8	19.3	7.5	33.0	13.0				
APR.	31.1	20.0	11.1	40.0	11.0	31.5	21.4	11.1	39.0	14.0	30.5	21.2	9.3	38.6	15.0	33.3	20.4	12.9	41.0	11.0	30.5	22.6	7.9	39.0	14.0				
MAY	35.7	24.3	11.4	49.0	16.0	36.3	25.0	11.3	47.8	20.0	35.1	24.5	10.6	40.8	20.2	38.3	24.6	13.7	46.0	18.5	33.6	25.8	7.8	43.0	21.5				
JUNE	36.7	26.9	9.8	49.0	20.0	38.5	28.4	10.1	51.2	20.0	37.1	27.3	9.8	45.6	24.0	40.2	27.3	12.9	46.5	19.0	35.1	28.4	6.7	43.0	18.0				
JULY	37.3	29.3	8.0	46.0	22.0	38.1	30.6	7.5	47.5	27.0	37.5	29.4	8.1	45.4	25.0	40.2	28.7	11.5	48.0	18.0	34.7	29.2	5.5	43.0	22.0				
AUG.	37.2	29.6	7.6	42.0	24.0	37.9	30.3	7.6	45.5	25.0	37.3	29.9	7.4	44.0	22.2	39.5	28.3	11.2	46.5	18.0	34.0	28.8	5.2	40.0	20.0				
SEPT.	36.0	26.8	9.2	42.0	22.0	37.1	28.1	9.0	44.5	22.0	36.0	28.3	7.7	41.6	24.0	38.7	26.1	12.6	45.5	15.0	33.3	26.8	6.5	40.0	22.0				
OCT.	33.4	22.5	10.9	42.0	17.0	35.0	24.2	10.8	42.0	14.0	34.5	25.5	8.6	40.6	21.0	36.2	23.1	13.1	43.0	11.0	32.1	23.5	8.6	39.0	18.0				
NOV.	29.1	17.6	11.0	35.0	9.0	30.6	17.7	12.9	37.5	10.0	29.0	21.1	7.9	34.5	15.0	30.9	18.0	12.9	38.9	6.0	28.5	19.7	8.8	32.0	14.0				
DEC.	24.7	13.9	10.8	32.0	6.0	25.8	13.9	11.9	32.0	2.0	24.5	17.4	7.1	29.0	10.8	25.7	13.9	11.8	32.0	3.0	25.5	7.3	8.2	29.0	9.0				

Tab. 1 — Analysis of temperatures (°C) at different stations. M= mean of maximum; m= mean of minimum; M-m= thermic excursion; Ma= absolute maximum; M_a= absolute minimum.

BANDAR LENGEH altitude: m. 13 year: 1966-77				BANDAR ABBAS altitude: m. 10 year: 1957-83				QESHM altitude: m. 31 year: 1965-74				MINAB altitude: m. 29 year: 1965-75				JASK altitude: m. 4 year: 1965-75			
P mm	R.D. > 1 mm	R.D. > 10 mm		P mm	R.D. > 1 mm	R.D. > 10 mm		P mm	R.D. > 1 mm	R.D. > 10 mm		P mm	R.D. > 1 mm	R.D. > 10 mm		P mm	R.D. > 1 mm	R.D. > 10 mm	
JAN.	41.6	3.6	1.4	58.7	3.6	1.0		50.4	4.0	2.0		60.7	4.0	2.0		64.1	3.9	2.3	
FEB.	21.8	3.1	0.8	42.3	3.1	0.9		34.5	3.0	1.0		46.6	3.0	1.0		28.7	2.0	0.9	
MAR.	11.7	1.0	0.4	34.1	2.5	0.5		19.1	1.0	1.0		14.8	1.0	1.0		12.3	0.8	0.5	
APR.	7.4	1.1	0.2	10.7	1.2	0.3		1.2	1.0	0.0		5.2	1.0	0.0		0.6	0.1	0.0	
MAY.	0.2	0.1	0.0	5.1	0.3	0.1		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0	
JUNE	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0	
JULY	0.3	0.3	0.0	0.7	0.2	0.0		1.3	0.1	0.0		0.0	0.0	0.0		0.8	0.3	0.0	
AUG.	10.3	0.2	0.2	2.3	0.2	0.1		0.8	1.0	0.0		2.6	0.6	0.0		0.4	0.4	0.0	
SEPT.	0.0	0.0	0.0	0.8	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0	
OCT.	0.8	0.1	0.0	2.8	0.1	0.1		0.5	0.0	0.0		0.9	0.7	0.0		13.4	1.3	0.3	
NOV.	1.3	0.5	0.0	6.5	0.5	0.3		8.1	1.0	0.0		6.8	1.0	0.0		1.5	0.3	0.0	
DEC.	18.6	2.0	0.6	22.1	2.0	0.5		10.0	1.0	0.0		14.8	1.0	0.0		31.4	1.9	0.6	
YEAR	114.0	12.0	3.6	186.1	13.7	3.8		125.9	12.1	4.0		152.4	12.3	4.0		153.2	11.0	4.6	

Tab. 2 — Monthly average precipitation (P= mm) and rainy days (R.D.).

	BANDAR ABBAS	JASK	MINAB	BANDAR LENGEH	QESHM
JAN./31	3.7	4.9	4.7	4.3	4.7
FEB./28	3.0	2.4	4.0	2.5	3.6
MAR./31	2.2	0.9	1.1	1.2	1.8
APR./30	0.7	0.0	0.4	0.8	0.1
MAY/31	0.3	0.0	0.0	0.0	0.0
JUNE/30	0.0	0.0	0.0	0.0	0.0
JULY/31	0.0	0.1	0.0	0.0	0.1
AUG./31	0.1	0.0	0.2	1.1	0.1
SEPT./30	0.1	0.0	0.0	0.0	0.0
OCT./31	0.2	1.0	0.1	0.1	0.0
NOV./30	0.4	0.1	0.5	0.1	0.8
DEC./31	1.4	2.4	1.1	1.9	0.9

Tab. 3 — Pluviometric coefficient of Angot.

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
BANDAR ABBAS	24.9	17.1	12.4	3.5	1.5	0.0	0.2	0.6	0.2	0.8	2.3	8.9
JASK	29.1	11.7	4.5	0.2	0.0	0.0	0.2	0.1	0.0	4.3	0.5	12.0
MINAB	25.9	19.2	5.3	1.7	0.0	0.0	0.0	0.7	0.0	0.3	2.4	6.0
BANDAR LENGEH	18.2	9.3	4.4	2.5	0.1	0.0	0.1	2.8	0.0	0.3	0.5	7.6
QESHM	20.9	14.1	7.0	0.4	0.0	0.0	0.4	0.2	0.0	0.2	2.8	3.9
BANDAR ABBAS	S.U.	S.A.	A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	A.
JASK	S.U.	A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	A.
MINAB	S.U.	S.A.	A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	A.
BANDAR LENGEH	S.A.	A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	A.
QESHM	S.U.	A.	A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.	E.A.

Tab. 4 — Monthly Aridity Index of De Martonne. (S.U. = Subhumid; S.A. = Semiarid; A. = Arid; E.A. = Extremely Arid.

considerably different from station to station: 5,2° C to 8,8° C at Jask, 6,7° to 10° C at Qeshm; 7,5° C to 12,7° C at Bandar Lengeh and Bandar Abbas, and 10,6° to 13,8° C at Minab. These may be explained in terms of geographical differences which exist between the stations. The lowest value of the monthly excursion is found at Jask, which is located by the sea shore, at a lower latitude than the other stations, and which has the coolest summer among all stations. The highest value of the monthly excursion is found at Minab, located about 20 Km away from the coast, towards the interior; it is the only station which lies very far from the sea shore.

Precipitations

Precipitation values are reported in Table 2. Mean monthly values show similar trends in all stations: maxima always fall in January - with values ranging from 64,1 mm (Jask) to 41,6 mm (Bandar Lengeh) - and an almost completely dry period occurs between May and September (some unimportant interruptions may occur in July and in August).

Mean annual values are very low. They range from a minimum of 114 mm (Bandar Lengeh) to a maximum of 186,1 mm (Bandar Abbas). There are just a few rainy days during the year: 11-14 days with more than 1 mm of rain, and approximately 4 days with more than 10 mm of rain.

We have outlined the seasonal regimen by ordering the seasons according to decreasing rainfall, in such a way that quarterly intervals include a solstice and an equinox. The results are, as follows:

- W, A, Sp, S, in Qeshm, Minab, Bandar Abbas, Jask;
 - W, Sp, S, A, in Bandar Lengeh;
- (W = Winter; S = Summer; A = Autumn; Sp = Spring).

Winter is therefore the most rainy season, with precipitation ranging from 82,2 mm (Bandar Lengeh) to 124,2 mm (Jask); whereas summer, which shows little or no precipitation, is always the driest season.

In order to determine the pluviometric regimen of the region, we have calculated Angot's Pluviometric Coefficient, by means of the expression $p = m/a$, where $A = (P.n)/365$, m = mean monthly rainfall and n = number of days in the month. The values obtained are given in Table 3. Some 50% of the rain distribution is concentrated in January, and the next highest percentage in February.

Aridity index

In order to outline the bioclimatic features of the area, we have calculated the Aridity Index, using the equation of De Martonne (1926) for the annual index, $A = P/(T + 10)$, and the expression $a = 12p/(t + 10)$ for the monthly index; where P = mean annual precipitation, T = mean annual temperature, p = mean precipitation, t = mean monthly temperature.

Table 4 shows that all the stations possess features which are proper of the extremely arid bioclimate; Bandar Abbas, however, shows transition towards the arid bioclimate.

Monthly analyses demonstrate that January is the only fairly moist month, at all

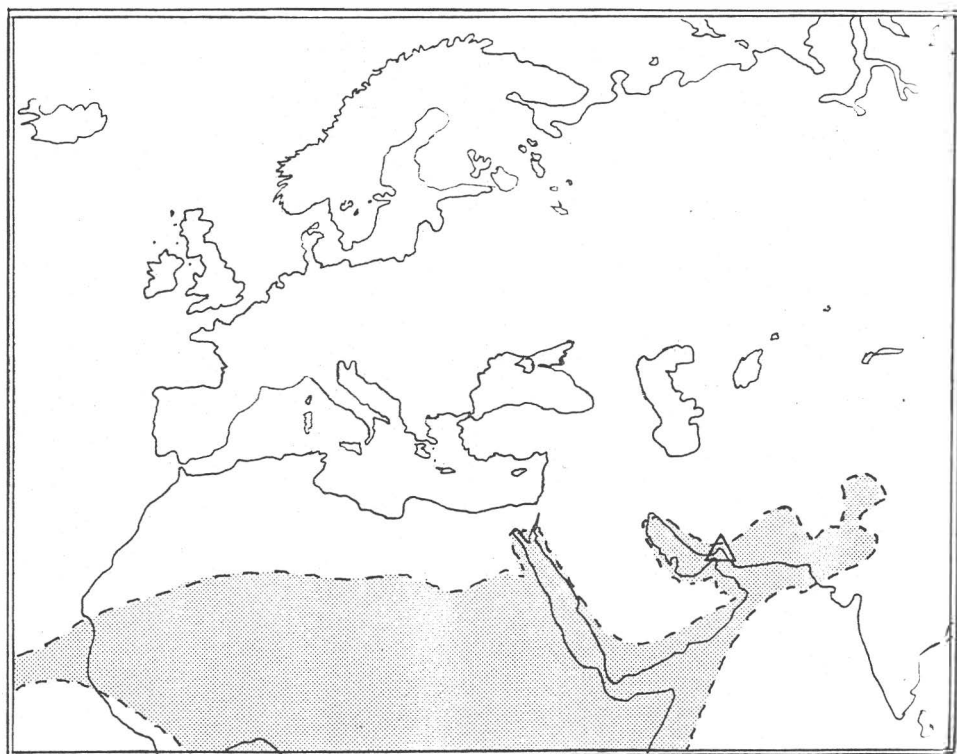


Fig. 2 — Map of the Sudanian Region (Zohary, 1973).

stations, except Bandar Lengeh, which is the most arid one.

Flora and Vegetation

The observations on the vegetation of Southern Iran which are given in the present work are, as said, preliminary. This is also due to the fact that field and laboratory identifications of the species which have been collected, has been quite arduous; this in turn, is due to the almost total lack of adequate basic documentation concerning the physical and biological environments of the region.

The region possesses several species, proper of the Nubo-Sindian Province (Sudanian region) (Zohary 1973), (Fig. 2) namely: *Calligonum crinitum*, *Zilla spinosa*, *Koelpinia linearis*, *Peryplocia aphylla*, *Tephrosia hausknechtii*, *Anabasis setifera*, *Salvadora persica*, *Heliotropium strigosum*, *Calotropis procera*.

Several species are of African origin, whereas other are typical of tropical Asia; the latter include *Prosopis spicigera*, *Euphorbia larica*, *Stocksia brahuica*.

The presence of several species of tropical origin is explained by the local bioclimatic conditions (i.e. high winter temperature, greater rainfall in the central plateau, and lower altitude, as previously discussed). The vegetation is extremely

discontinuous and irregular; preferential sites for plant growth are the zones with a richer water supply. Hence, the vegetation tends to concentrate in wadis and oases, the most favourable areas as far as the availability of water is concerned.

The vegetation is always extremely specialized (xerophytic) and selected, as it must face the drastic irregularities of the hydrographical system, as well as the excessive summer heat.

Distinctive features of the plant species include their rather short period of biological activity, the possibility of entering into a state of quiescence during the adverse periods - by means of different mechanisms - and special morphoanatomic features, e.g. an extremely marked growth of the root apparatus. A number of species, including several Gramineae of sea-shore and interior sandy environments (e.g. *Pennisetum divisum*, *Panicum turgidum*), are nevertheless able to benefit from the water condensation caused by thermal variation. Other adaptations to the environment include wax formation of the epidermal tissues, and the reduction of the area of the surface which are likely to lose considerable amounts of water as a consequence of evaporation); the latter adaptation is found in *Euphorbia larica* (Fig. 5). Cutinization of leaf epidermis occurs in the majority of trees of the region (*Prosopis spicigera*, *Acacia tortilis*, *Salvadora persica*, *Ziziphus spina-christi*, etc.).

The vegetation structures which have been identified during the present preliminary investigation of Southern Iran, are referred to the vegetation structures identified by Giacomini & De Marco (1975) in Saudi Arabia.

Basically, geobotanical and geomorphological criteria have been used to outline the prominent features of the vegetation structures; this approach has also provided a basis for the field work methodology.

Pseudo-steppes

Pseudo-steppes have been found in a coastal environment and in the innermost alluvial plains.

A distinctive feature of pseudo-steppes is the presence of several deep-rooted phanerogams, including *Calligonum crinitum* (Photo 4), *Acacia tortilis*, *Rhazia stricta*, *Fagonia* sp.pl., *Calotropis procera*, *Cyperus conglomeratus*, *Haloxylon salicornicum*, *Aristida coerulescens*, etc.

This community is found on sandy and muddy substrata.

Several ephemeral species (mostly Gramineae), highly palatable for cattle, cover the soil especially after showers. On the whole, this formation supplies a good quantity of plant biomass for stock-raising; it also contributes greatly to the stabilization of sand.

Scrub-steppes

Scrub-steppes have been found in the coastal area and, to a greater extent, in the alluvial plains.

The floristic composition of the scrub-steppes is not significantly different from the one of the pseudo-steppe. The differences lie in the increase of the number of trees and shrubs, which are always isolated, and of herbaceous plants. The latter,

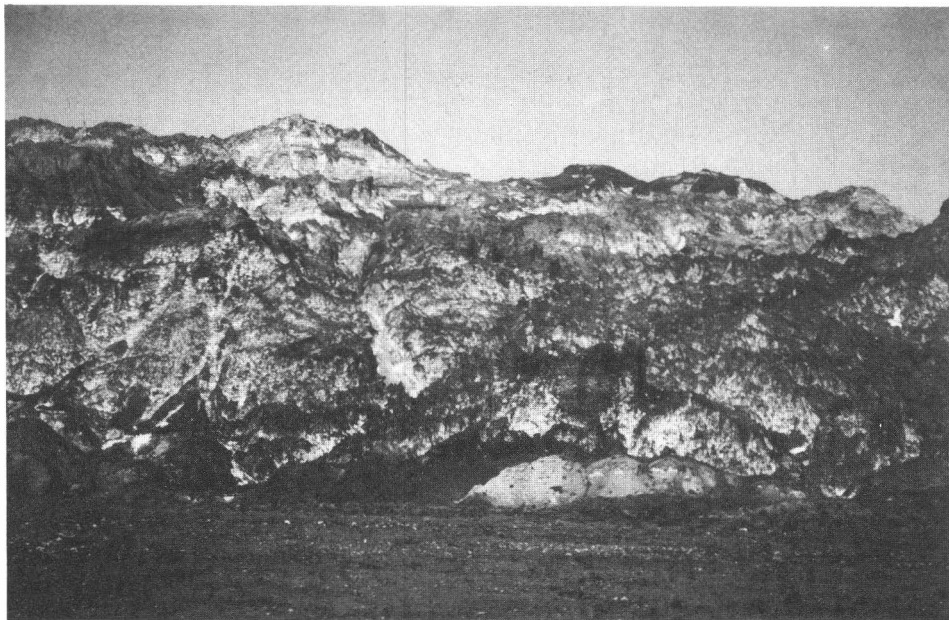


Fig. 3 — A landscape of salt plug domes.

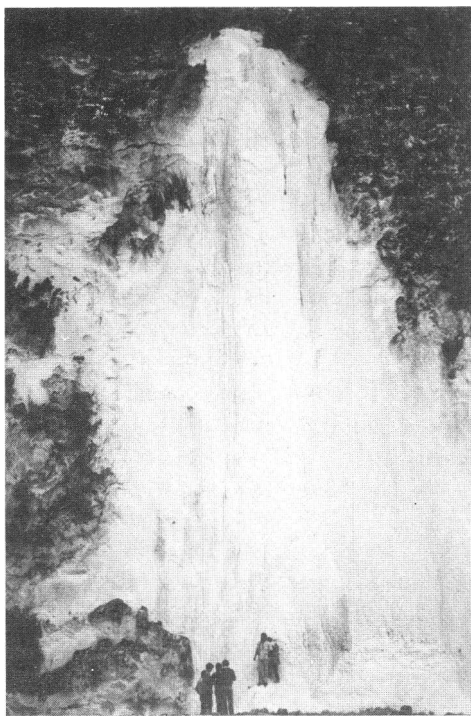


Fig. 4 — Salt fall of a salt dome.

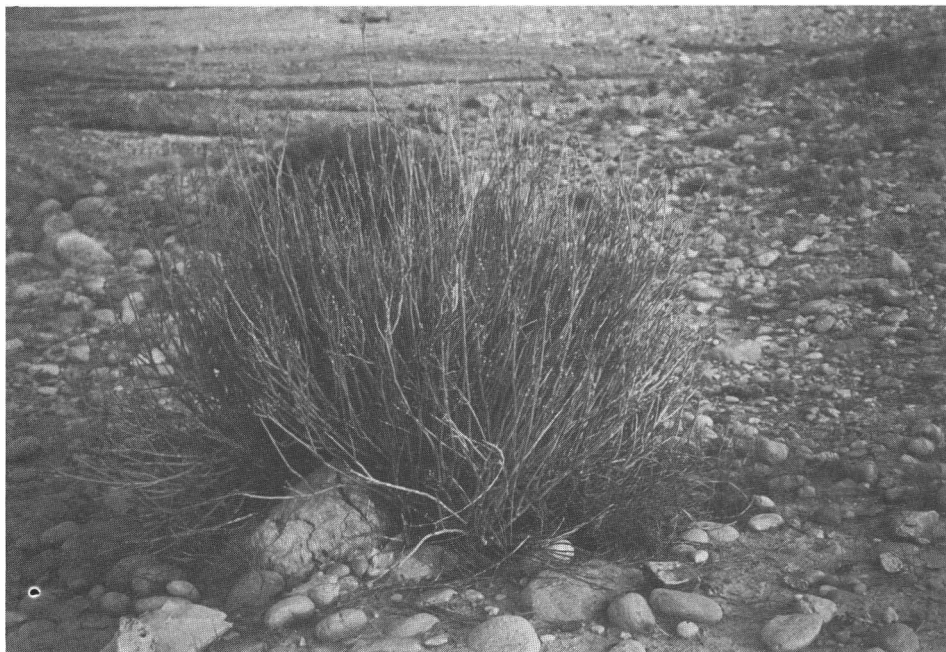


Fig. 5 — *Euphorbia larica* Boiss.

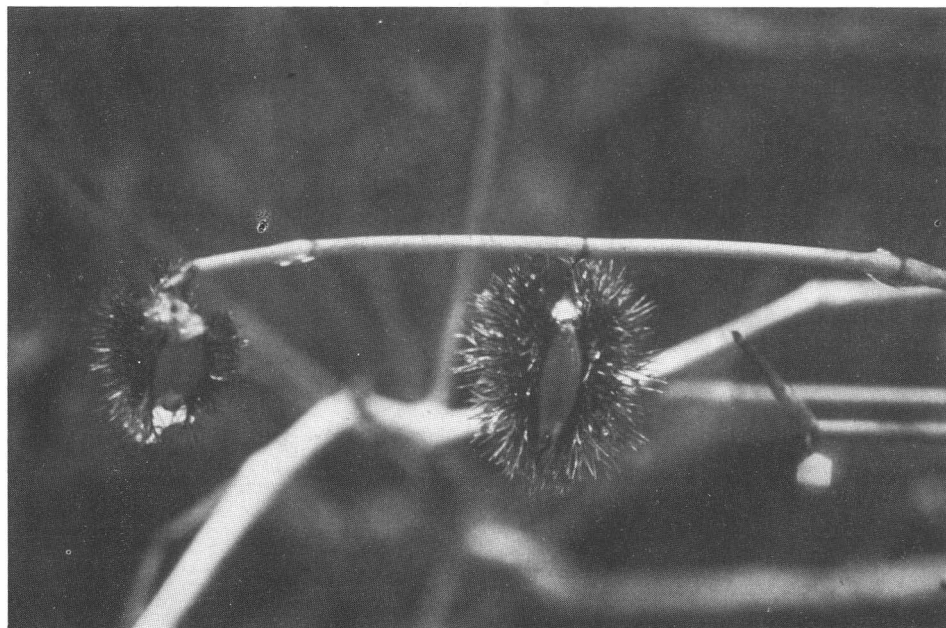


Fig. 6 — *Calligonum crinitum* Boiss.

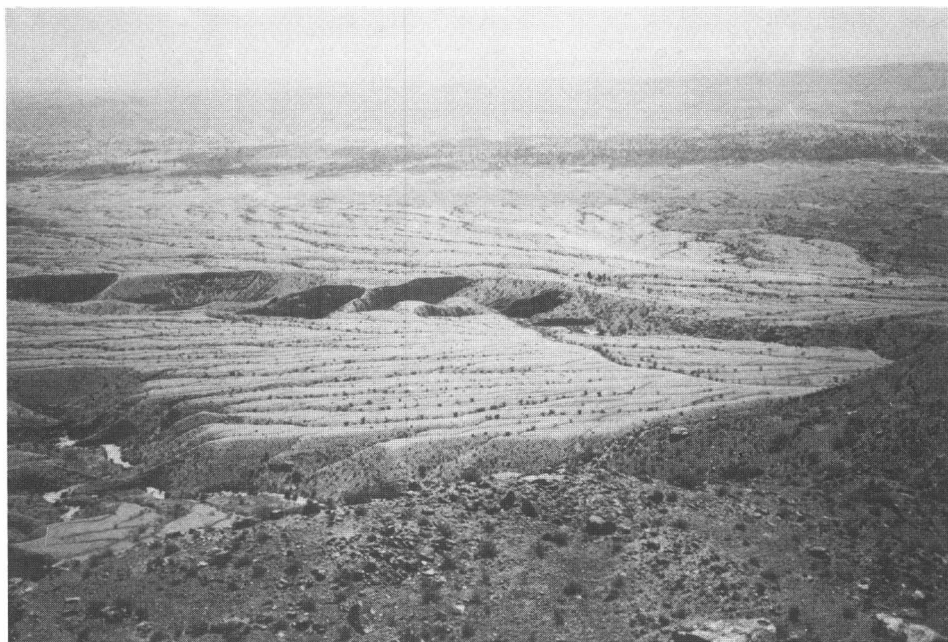


Fig. 7 — Typical rocky xerophilous scrub.

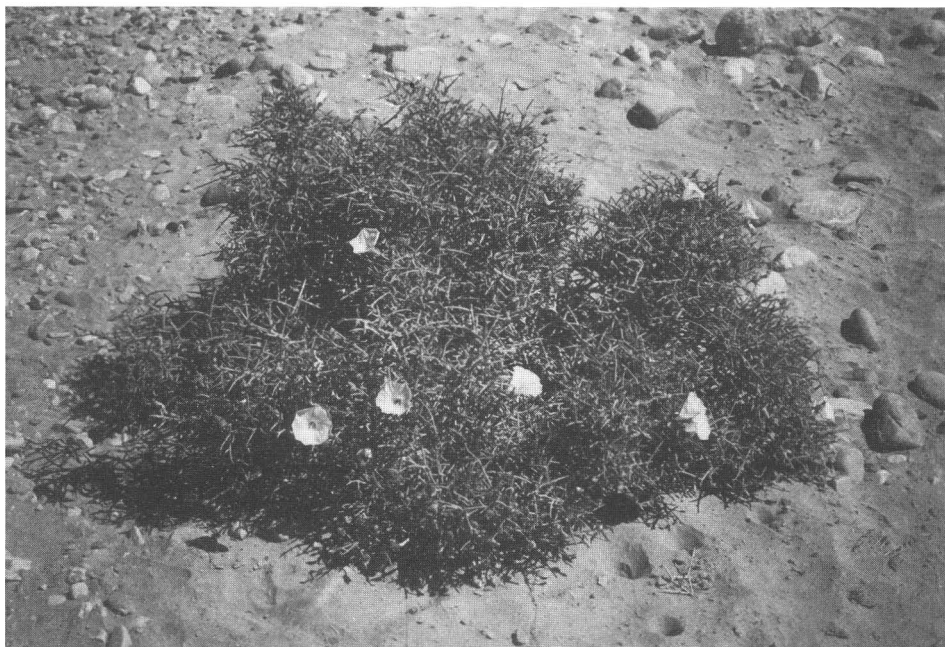


Fig. 8 — *Convolvulus spinosus* Burm.

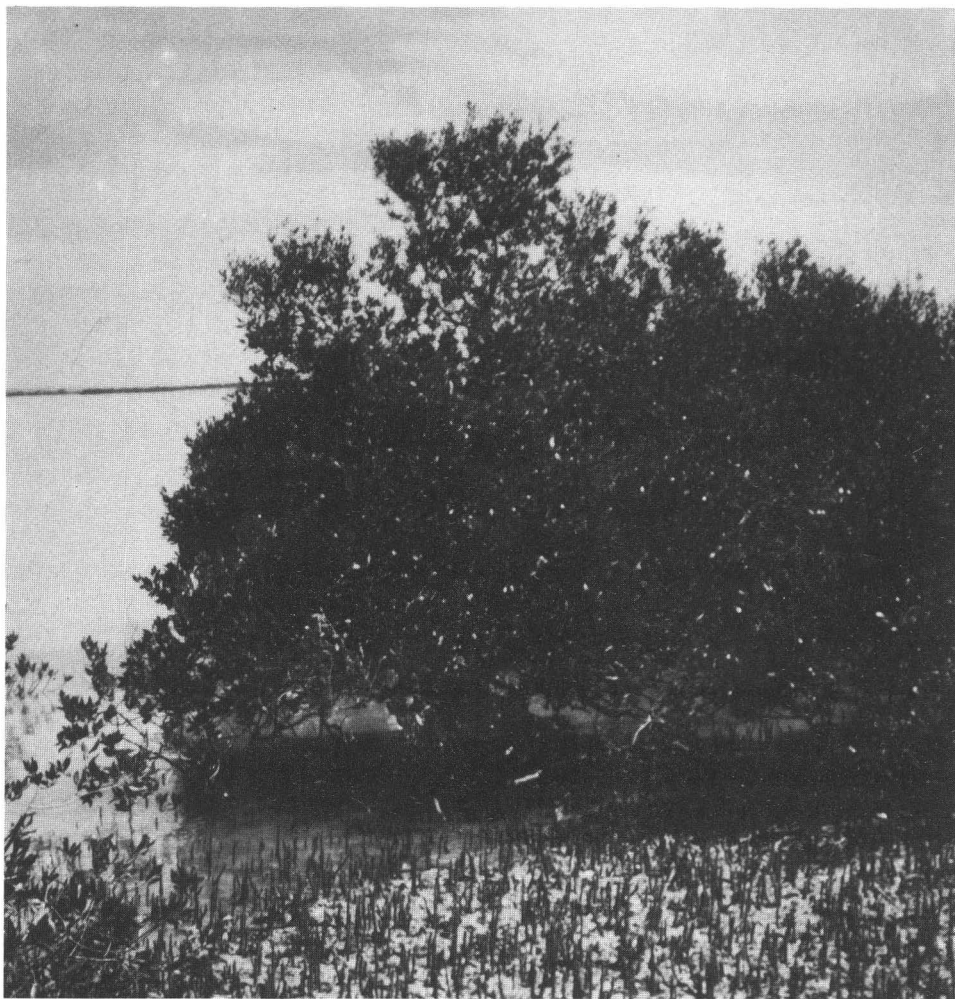


Fig. 9 — *Avicennia marina* (Forsk.) Vierh.

which have a suffrutescent habit, are found in small colonies; they include *Haloxylon salicornicum*, *Rantherium epapossum*.

The herbaceous-shrubby layer is similar to the one of the pseudo-steppes. Just as pseudo-steppes, scrub-steppes provide good quantities of plant biomass for stock-raising and human utilization.

Rocky xerophilous scrub

This type of community grows where rocky outcrops interrupt the continuity of the ground or where the ground surface is composed of rather coarse material (e.g. cones, Fig. 7).

It is a very open shrubland where trees occur sporadically. The latter are simply shrubs which are developed in particular morphologically more favourable zones.

The most representative species are *Acacia tortilis*, *Ziziphus spina-christi*, *Calotropis procera*, *Ziziphus nummularia*, *Periploca aphylla*, *Amygdalus arabica*, *Aerva persica*, *Prosopis spicigera*, *Euphorbia larica*, etc..

The presence of ephemeral species, - mostly Gramineae and Leguminosae is almost entirely confined to the rainy periods. They represent an excellent forage.

In the piedmont zone and the alluvial plains, and in the presence of noticeable quantities of detritus material, this formation takes a peculiar appearance which is connected with copious presence of *Euphorbia larica* (Fig. 5), a large, semiglobular pale-green shrub. Several species coexist with it, including *Ephedra pachyclada*, *Convolvulus oxysepalus*, *C. acanthoclados*, *C. spinosus* (Fig. 8), *Gaillonia aucheri*.

Riparian formation

Riparian formations, which are located along the wadis, are lushier formations than the ones already examined. This is due to more favourable environmental conditions and to the greater availability of water. The presence of trees, such as *Acacia tortilis*, *Prosopis spicigera*, *Ziziphus spina-christi*, is a distinctive feature of these formations. *Tamarix gallica* is the dominant species where water is available in greatest quantity. It may, at times, originate dense bushes, and it is frequently used for house-building if it reaches tree-like dimensions. *Calotropis procera*, *Salvadora persica*, *Aerva persica*, *Cyperus conglomeratus*, etc., may be found in the oases and along the channels.

Sabkas formation

Sabkas formations occur in areas where many plains, generally of a considerable extension, are present.

These areas are located along the coast, or in some depressed zones of the interior. They have flat morphology, and possess a saline crust on the ground surface. The vegetation may be monophytic and discontinuous; completely bare zones of considerable extension may be found. Typical species are: *Suaeda vermiculata*, *Halocnemum strobilaceum*, *Siedlitzia rosmarinus*, *Zygophyllum coccineuma*, *Limonium* sp..

Hydro- and halophytes are found in the areas where water comes to, or at least close to, the ground surface. They include *Tamarix gallica*, *Cyperus conglomeratus*.

At the border of the Sabkas formations, pseudo-steppes are frequently found. Aeolian deposition processes on the salt plains have originated a microdunal morphology similar to the one of pseudo-steppes. However, the vegetation of these areas shows some striking differences with the one of true pseudo-steppes, being strongly influenced by the underlying saline substratum.

The dominant species in these areas is *Haloxyton salicornicum* stabilizer of the dunes. Other phreatophytes, which are typical of a sandy environments, are found with it, namely *Calligonum crinitum*, *Limonium* sp., *Cyperus conglomeratus*, *Panicum turgidum*.

Oases

Towards the wasi zone downhill, the alluvial plains consist of pebble, sand and mud material which has been deposited by the watercourses, the flow of which is extremely variable. The most important oases are Minab and Bandar Abbas, which lie at the foot of the Kuh-e Ghenu.

Presently, the cultivation of the oases is rather diversified; culture of *Phoenix dactylifera* predominates, although *Citrus* fruits and other tropical and sub-tropical fruits are cultivated in some oases where environmental conditions are suitable (*Carica papaya*, *Cocos nucifera*, *Mangifera indica*, *Ficus religiosa*).

In the oases with a limited availability of water (Bandar Lengeh and Demilu), *Phoenix dactylifera* is the only feasible culture.

Vestiges of cultivated fields - presently deserted and invaded by spontaneous species - have frequently been found within the boundaries of oases and ex-oases close to Minab and all along the way to Jask.

Mangroves

In proximity of the mouths of the most important rivers of the region, conspicuous deposition of muddy sediments has originated a coastline with a peculiar morphology, of modest depth, presenting small islands which are partially or totally submerged according to the tide.

In the Strait of Clarence, (formed by a syncline lying between the anticline of Qeshm Island and the terra firma) the contribution of fine sediments from the Rud-e Kull, two important rivers, has caused the formation of a large shallow submerged delta, where the most important mangrove formation of the region is present. This formation has a geomorphological action, since it tends to stabilize the fine sediments and, consequently, to favour the constant advance of the coastline.

The above mentioned formation, which probably had a certain economic importance in the past, is decreasing nowadays; its vestiges are found at the mouths of the rivers of the entire region. The regression may be explained in terms of the global decrease of the freshwater flow originating in the mountains behind the area.

The presence of one single woody species (*Avicennia marina*) (Fig. 9) is a distinctive feature of this formation. It is well adapted to its environment, as it possesses a special glandular system for eliminating salts in excess over its requirements. Similar structures are also found in several species of the genus *Tamarix*. It is extremely frequent in the sea tract between the northwest coast of Qeshm Island and the deltas of the rivers Rud-e Kul and Rud-e Mehran, where it forms very dense populations.

Several attributes make this environment extremely interesting for the naturalist, as witnessed by the fact it is a Natural Park and, since 1976, a UNESCO Biosphere Reserve within the MAB Project.

It is the favourite nesting site for numerous species of birds; to these, and to the plants themselves, the conspicuous production of organic matter - which causes the development of very dense phyto - and zooplankton populations - may be ascribed. The abundant plankton, in turn, accounts for the presence of numerous

species of fishes and crustaceans.

The economic potential of mangroves (e.g. timber and forage production), of equal importance nowadays as in the past, may be partly explained in terms of their proximity to the terra firma and of the exiguous depth of the areas where they are found, which make them quite easy to exploit.

Floristic list

The list reported in the appendix contains a first set of 174 species, belonging to 48 families, which have been collected during the March-April 1983 expedition. Particular attention has been given to the species found in the following areas: Bandar Abbas, Bandar Lengeh, Minab, Jask and the Kuh-e Genu.

Taxonomical identification has been accomplished by using the works of Rechinger (1963-1982), Parsa (1951-1960), Ozenda (1958), Zohary (1955-1978) Boissier (1867-88), Pignatti (1982).

Whenever possible, the nomenclature follows K.H. Rechinger's "Flora Iranica" not yet finished.

The coupling of the plant species with their life form has enabled us to elaborate the following biological spectrum:

P = 10, 91 %; Ch = 20,11%; H = 14,36%

Pn = 15,51%; G = 2,87%; T = 36,20%

It may be seen that Therophytes are present in a high proportion; this is probably due to the fact that the specimens have been collected in March, immediately after the rainy season.

The percentage of Chamaephytes and Nano-Phanerophytes, is also quite high, its cumulated value being of 35,62%.

Chorologically, the species hereby reported belong to the following phytogeographical classes: Mediterranean (20,11%), Saharo-Sindian (20,11%), Tropical (10,34%), Irano-Turanian (6,32%), Endemic (2,87%), Cosmopolitan (3,44%), Cultivated (3,44%), Circumboreal (0,57%), Eurasiatic (0,57%), Ibero-Macaronesian (0,57%), Paleotemp. (0,57%).

Among the Saharo-Sindian we recall: *Koelpinia lineris*, *Salvia aegyptiaca*, *Senecio desfontanei*, *Fagonia bruguierii*, *F. olivierii*, *Matthiola longipetala*, *Trigonella stellata*, *Maerua crassifolia*, *Calligonum crinitum*, *Anabasis setifera*, *Cornulaca monacantha*.

Several endemic species have been found, e.g. *Fortuynia bungei*, *Convolvulus acanthoclados*, *C. spinosus*, *C. oxysepalus*.

The most representative Mediterranean species are, *Emex spinous*, *Rumex cyprus*, *Haloplepis perfoliata*, *Mesembrianthemum nodiflorum*, *Erodium laciniatum*, *Helianthemum salicifolium*, *Teucrium polium*, *Crupina crupinastrum*, *Aeluropus lagopoides*.

For some 24% species, it has not been possible to determine the phytogeographical classes to which they belong, since the data available in the literature was not sufficient for attaining satisfactory conclusion.

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Appendix: Floristic list

PTERIDOPHYTAE

PHILOGLOSSACEAE

G Ophioglossum vulgatum L. Circumbor.-

SINOPTERIDACEAE

H Cheilanthes pteridioides Reinhardt - Medit. Iran. Turan.

GYMNOSPERMAE

CUPRESSACEAE

P Juniperus excelsa M.B. - Iran. Turan. - Kuh-e - Geni.

EPHEDRACEAE

Pn Ephedra ciliata Fish et Mey ex C.A. Mey - Kuh-e Geni

Pn Ephedra pachyclada Boiss. - Kuh-e - Geni

ANGIOSPERMAE

MORACEAE

P Ficus religiosa L. - Cult.

POLYGONACEAE

T Emex spinosus (L.) Campd. - Medit.

T Rumex vesicarius L. - Sah. Sind.

T Rumex cyprius Murb. - Medit. Trop.

Pn Calligonum crinitum Boiss. - Sub. Sah. Sind.

T Polygonum aviculare L. - Cosmop.

CHENOPODIACEAE

T Chenopodium murale L. - Subcosmop.

Ch Halopeplis perfoliata Forsk. - Medit.

Pn Halocnemum strobilaceum (Pall.) M.B - Medit. Iran. Tur.

Ch Salicornia fruticosa L. - Medit. Afr.

Ch Suaeda cfr. fruticosa Forsk. - Sah. Arab.

T Suaeda maritima (L.) Dumort - Cosmop.

Pn Suaeda vermiculata Forsk. - Sah. Arab.

Pn Seidlitzia rosmarinus (Ehrenb.) Bge. - Sah. Sind.

Ch Anabasis setifera Moq. - Sah. Sind.

Pn Salsola vermiculata L. - S. Medit.

Pn Haloxylon aphyllum Minkv.

Ch Cornulaca monacantha Del. - Sah. Sind.

AMARANTHACEAE

Ch Aerva persica (Burnm.) Merr. var. bovei (Webb.) Chiov. - Paleotrop.

NYCTAGINACEAE

H Boerhavia diffusa L. - Paleotrop.

AIZOACEAE

T Mesembrianthemum nodiflorum L. - Medit. Afr.

PORTULACACEAE

Pn Gymnocarpos decander Forsk. - Sah. Arab.

CARYOPHYLLACEAE

T Polycarpon tetraphyllum (L.) L. - Medit.

T Spargula fallax (Lowe) E.H.L. Krause - Medit. Atl.

T Silene villosa Forsk. in Parsa

PAPAVERACEAE

H Oxylobum vitellinum Boiss. et Buhse - Kuh-e - Genu

CAPPARIDACEAE

- Pn Maerua crassifolia Forsk. - Sah. Sind.
Pn Capparis decidua (Forsk.) Edgew. - Trop.
Pn Capparis spinosa L. - Subtrop.
Ch Cleome oxypetala Boiss.
Ch Dipterygium glaucum Decne

CRUCIFERAE

- T Diplotaxis griffithii (Hook. et Thoms.) Boiss - Bandar-Abbas
Ch Physorrhynchys brahuicus Hook. - Sah. Sind.
T Eruca sativa Miller - Medit. Tur.
Ch Fortuynia bungei Boiss. - Endem. (Iran. Pakistan)
T Moricandia clavata Boiss. et Reut - E Sah. Arab.
Ch Stroganowia persica N. Bush
Pn Farsetia longisiliqua Decne
Ch Farsetia heliophila Bge.
H Diceratella canescens (Boiss.) Boiss.
H Matthiola farinosa Bge. ex Boiss. - Iran. Tur.
T Matthiola longipetala (Vent.) DC. - Sah. Sind. - Gemi Park
T Malcomia bungei Boiss. var. glabrescens Boiss. (ex Parsa)

RESEDACEAE

- T Reseda muricata Presl. cfr. var. undulata Post. - E. Sah. Sind.

ROSACEAE

- P Crataegus meyerii A. Pojark (= C. pectinata Meyr) - Iran. Tur.
Pn Amygdalus arabica Olivier - Iran. Tur.

LEGUMINOSAE

- H Astragalus cfr. schahrudensis Bge. - Endem.?
Pn Astragalus cfr. fasciculifolius Boiss. - Iran. Tur.
Pn Astragalus cfr. strictifolius Boiss. - Iran. Tur.
T Astragalus cfr. camptoceras Bge. - Iran. Tur.
T Medicago rigidula (L.) All. - Eurimedit.
T Medicago denticulata Willd. - Eurimedit. M.t Gemù
T Scorpiurus sulcata L. - Medit.
T Trigonella uncata Boiss. et Noe - Iran. Tur.
T Trigonella teheranica Bornm.
T Trigonella stellata Forsk. - Sah. Sind.
T Hippocrepis bornmuelleri Hskn.
Pn Indigofera intricata Gouan. - Paleotrop.
T Lotus cfr. schimperii Steud.
P Acacia tortilis (Forsk.) Willd.
P Acacia arabica (Lam.) Willd. - Afr. Trop.
P Acacia nubica Benth.
P Acacia ehrenbergiana Hayne
P Cassia obovata Collad. - Sud Dec. Sah.
Pn Tephrosia hausknechtii Bornm. - Trop. Mt. Gemù
P Prosopis spicigera L.
Ch Taverniera spartea DC.
T Vicia angustifolia L. - Eurimedit.
T Artyrolobium trigonelloides Jaub. et Sp. var. subuniflorus Bornm. - Sah. Arab.

GERANIACEAE

- H Monsonia heliotropioides (Cav.) Boiss. - Medit.
T Geranium mascatense Boiss.
T Erodium laciniatum (Cav.) Willd. - Medit.

ZYGOPHYLLACEAE

- H Fagonia olierii DC. - Sah. Sind.

- H Fagonia indica Burm. fil. - Sah. Sind.
H Fagonia bruguierii DC. - Sah. Sind.
T Zygophyllum simplex L. - Afr. Trop. Arab.
Ch Zygophyllum eurypterum Boiss. et Buhse - Iran. Tur.
Ch Zygophyllum propinquum Decne
T Tribulus terrestris L. - Cosmop.

EUPHORBIACEAE

- Ch Chrozophora obliqua (Vahl.) Juss. ex Spreng. - Iran. Tur.
T Euphorbia turcomanica Boiss.
Pn Euphorbia tirucalli L.
Pn Euphorbia larica Boiss.
Pn Euphorbia osyridea Boiss.

RUTACEAE

- Ch Haplophyllum pedicellatum Bge. ex Boiss.
Ch Haplophyllum tuberculatum (Forsk.) Juss. - Sah. Arab.

ANACARDIACEAE

- P Mangifera indica L. - Cult.

SAPINDACEAE

- P Dodonaea viscosa (L.) Jacq.
Pn Stocksia brahuica Benth.

SALVADORACEAE

- Pn Salvadora persica L.

RHAMNACEAE

- P Ziziphus spina-christi (L.) Willd. - Trop.
P Ziziphus nummularia (Burm. fil.) Wight. et Arn

MALVACEAE

- Ch Abutilon muticum (Delile ex DC.) Sweet - Trop.
T Malva parviflora L. - Medit.

CISTACEAE

- Ch Helianthemum lippii Pers. - Sah. Sind.
T Helianthemum salicifolium (L.) Miller - Medit.

TAMARICACEAE

- P Tamarix gallica L. - N. Trop.

CARICACEAE

- P Carica papaya L. - Cult.

CUCURBITACEAE

- T Citrullus colocynthis Schrad. - Trop. Medit.

PRIMULACEAE

- T Anagallis arvensis L. - Medit.

APOCYNACEAE

- Ch Rhazya stricta Decne.

ASCLEPIADACEAE

- Pn Periploca aphylla Decne. - Sah. Arab.
P Calotropis procera (Wild.) R. Br. - Sahelo Sah.
Pn Leptadenia pyrotecnica (Forsk.) Decne. - Trop.

CONVOLVULACEAE

T	Cuscuta sp.
T	Cressa cretica L. - Subcosmop.
Ch	Convolvulus acanthoclados Boiss. - Endem.
Ch	Convolvulus spinosus Burm. - Endem.
Ch	Convolvulus oxysepalus Boiss. - Endem.
H	Convolvulus sericeus Burm.
G	Convolvulus arvensis L. - Euras.

BORAGINACEAE

Ch	Heliotropium cfr. strigosum Willd. - Sah. Sind.
Ch	Heliotropium cfr. ophioglossum Stocks - Sah. Sind.
Ch	Heliotropium persicum Burm.
Ch	Heliotropium rotundifolium Sieb.
T	Arnebia hispidissima (Lehm.) DC; - Sah. Arab. Onosma sp.

AVICENNIAACEAE (ex Rechinger)

P	Avicennia marina (Forsk.) Vierh.
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LABIATAE

	Micromeria cfr. mirtifolia Boiss. et Hohen
Ch	Teucrium polium L. - Medit.
Ch	Salvia aegyptiaca L. - Sah. Sind.

SOLANACEAE

Pn	Lycium cfr. intricatum Boiss. - Medit.
H	Hyoscyamus nutans Shonebeck - Temesy - Sah. Sind.
T	Solanum melongena L. - Cult.

OROBANCHACEAE

T	Cistanche tubulosa (Schrenk.) R. Wight. - S. Medit.
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RUBIACEAE

T	Galium setaceum Lamk. - Medit. Euras.
Pn	Gaillonia aucheri Guill.

PLANTAGINACEAE

T	Plantago ovata Forsk. - Medit.
T	Plantago bellardii All. - Medit.
T	Plantago psyllium L. - Medit.

COMPOSITAE

Pn	Rhanterium epapposum Oliver
Ch	Phagnalon nitidum Fres.
T	Anthemis cfr. gayana
Ch	Artemisia herba-alta Asso - Iran. Tur.
T	Senecio desfontanei Druce - Sah. Sind.
H	Centaurea solstitialis L. - Medit.
T	Crupina crupinastrum (Moris.) Vis. - Medit.
T	Koelpinia linearis Pallas - Sah. Sind.
T	Urospermum picroides (L.) Desf. - Medit.
Ch	Launaea acanthodes (Boiss.) O. Kunze - Iber. Maur. Macar.

LILIACEAE

H	Asphodelus fistulosus L.
N	Asphodelus tenuifolius Cav. - Paleosubtrop.
G	Tulipa violacea Boiss. et Buhse
G	Nectaroscordum tripedale (Trautv.) Grossh. (= Allium roseum) L. - Medit.
G	Gagea reticulata (Pall.) Meyr - Iran. Tur.

GRAMINEAE

T	<i>Lamarckia aurea</i> (L.) Moench - Medit. Tur.
T	<i>Bromus tectorum</i> L. - Paleotemp.
T	<i>Trachynia distachya</i> (L.) Link (= <i>Brachypodium d. Beauv.</i>) - Paleosubtrop.
T	<i>Schismus arabicus</i> Nees - S. Medit. Tur.
T	<i>Aristida coerulescens</i> Desf. - Sahara - Sind.
T	<i>Aristida plumosa</i> L.
T	<i>Stipagrostis hirtigluma</i> (Steud.) De Winter - Trop.
H	<i>Stipa hausknechtii</i> Boiss.
H	<i>Aeluropus lagopoides</i> (L.) Trin ex Thawaites - S. Medit. Tur.
T	<i>Dactyloctenium aegyptium</i> (L.) P. Beauv. -Paleotrop.
H	<i>Panicum turgidum</i> Forsk. - Sah. Sind.
H	<i>Pennisetum flaccidum</i> Griseb.
H	<i>Pennisetum divisum</i> (Gmel.) Henrard
H	<i>Pennisetum orientale</i> L. G. Rich.
T	<i>Cenchrus pennisetiformis</i> Hochst. et Steud. ex Steud.
T	<i>Cymbopogon martinii</i> (Rosb.) Watson

CYPERACEAE

H	<i>Scirpus wardianus</i> J.R. Drummond
H	<i>Cyperus esculentus</i> L. - Subtrop.
H	<i>Cyperus conglomeratus</i> Rotb. - Sah. Sind.
H	<i>Cyperus rotundus</i> L. - Subtrop. (Subcosmop.)

PALMAE

P	<i>Phoenix dactilifera</i> L. - Cult.
P	<i>Cocos nucifera</i> L. - Cult.

Authors' address:
Dr. C. Marinucci
Dr. M.L. Leporatti
Dr. E. Lattanzi
Dipartimento di Biologia Vegetale
Università "La Sapienza"
Città Universitaria
00100 Roma

ÉTUDE SYMPHÉNOLOGIQUE D'UNE FORÊT THERMIQUE VALENCIENNE (VALENCIA, ESPAGNE) À *QUERCUS ROTUNDIFOLIA* LAM. ET *FRAXINUS ORNUS* L. I. FLORAISON.

E. LAGUNA et R. CURRÀS

Keywords: Phenology, Holm Oak, Thermomediterranean, Valencia.

Abstract. The flowering of *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* Costa, Peris & Figuerola

The flowering of *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* Costa, Peris & Figuerola 1982 is studied during the dry year 1983 in the "carrascal" maquis-wood of the Barranco Real (Valencia, Spain). The formation is characterised by high frequencies of multiple flowerings - more of one flowering along the year -. The "optimum" flowering - highest frequency in a taxon - is pertaining to the spring, while the "suboptimum" flowering - low frequencies in a taxon - is autumnal and it is related with the season whose pluviometric values are highest.

Introduction

Costa et al. (1982) ont défini la végétation climacique valencienne à l'étage thermoméditerranéen. Cette formation, le *Rubio longifoliae-Quercetum rotundifoliae* Costa, Peris & Figuerola 1982 est très dégradée au territoire valencien, due le fort effet anthropique. Ces effets seraient déjà intenses dès la Néolithique, selon Vernet et al. (1982).

Le *Rubio longifoliae-Quercetum rotundifoliae* Costa, Peris & Figuerola 1982 est la dernière phase de la série de végétation valencienne thermique à chêne vert. Dans les sols des vallées et des falaises se définit une sous-série à *Fraxinus ornus* L. (voir Costa, 1982), auquel on rapporte ce travail.

Pendant l'année 1983 nous avons réalisé une étude symphénologique du *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* Costa, Peris & Figuerola 1982 où nous déterminons l'influence des facteurs climatiques sur la présence de phénomènes phénologiques peu fréquents. Durant 1981 et 1982 nous avons observés une haute fréquence des floraisons multiples et des phases d'émission du feuillage très nombreuses.

L'aire d'étude

L'aire d'étude fut le "Carrascal del Collado Blanco", situé dans la "Sierra del Caballón" - centre de la province de Valencia -. Il s'agit d'un maquis haut situé sur les sols pierreux au pied d'une falaise dolomitique. Les données géographiques et les descriptions générales, dans Curràs & Laguna (1985, 1986).



Fig. 1 — Localisation du milieu dans l'ensemble de la Peninsule Ibérique.

Le sol trouvé au "carrascal" - forêt ou maquis dense dominées par *Quercus rotundifolia* Lam. - est inclus dans le type des Rendzines dolomitiques (Duchaufour, 1965). Il s'agit d'un sol peu profond, sur une surface inclinée - pentes proches du 100% -, développée d'après les rochers dolomitiques. Le sol présente une dynamique de migration descendante et oblique des cations et une décarbonatation superficielle notable - carbonates totaux: 0.72% d'après l'analyse par le calcimètre de Bernard -. La présence d'éléments calcifuges, tels que l'*Asplenium onopteris* L., est presque constante. Les figs. 1 et 2 permettent la localisation du "Carrascal" dans l'ensemble Ibérique et Valencien.

Si nous considérons les modèles structuraux de Dansereau (1951) et Dansereau & Arros (1959), la structure du "carrascal" est difficile à représenter étant donné qu'il a un nombre élevé de strates. Les écosystèmes forestiers thermiques valenciens (voire délimitation en Costa, 1982) présentent une forte tendance à la stratification multiple. Une description physionomique est donnée à la fig. 3.

La stratification est un des facteurs les plus importants (Braun-Blanquet, 1950 et 1979) pour l'étude symphénologique. Nous mettons en évidence la stratification du "carrascal" selon le schéma suivant:

- 1) - Strate arborescente: Avec la dominance de *F. ornus* L. sur les 3-4 m. et celle de *Q. rotundifolia* Lam. aux 3 m.
- 2) - Strate arbustif supérieur: Très dense et jusqu'à 2.5 m. de hauteur. Composé par des essences arbustives dominantes comme *Juniperus oxycedrus* L., *Phillyrea*

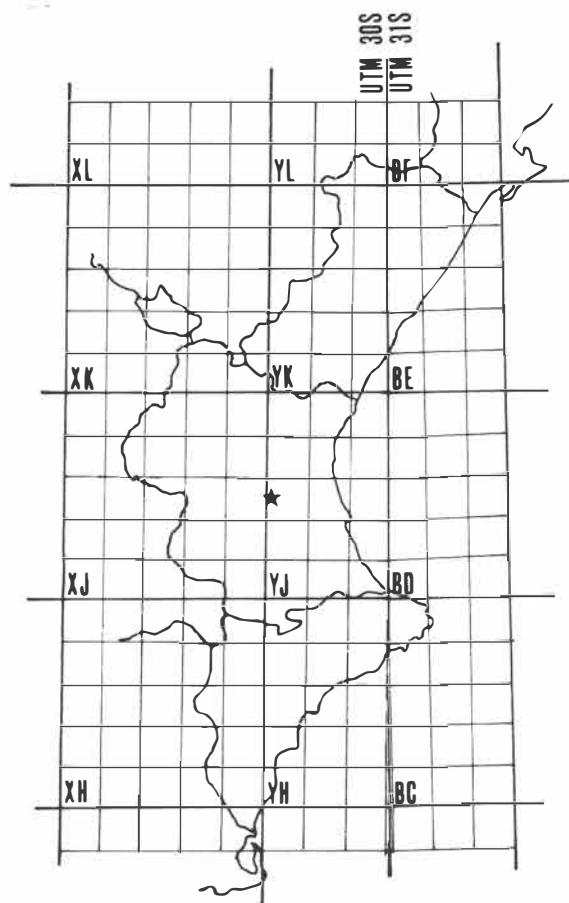


Fig. 2 — Localisation du milieu dans l'ensemble régional et au réticule UTM (réseau fin, 20 x 20 km.).

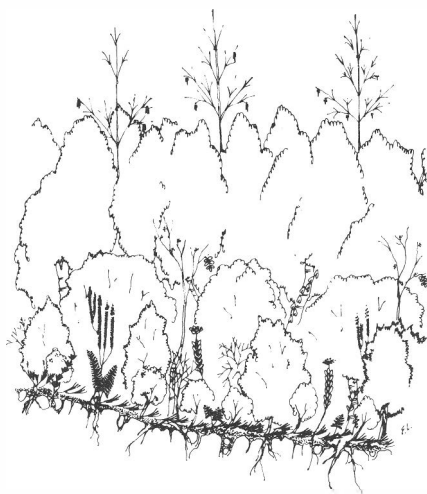


Fig. 3 — Schéma structurale de la végétation.

angustifolia L., *Genista valentina* (Willd. ex Sprengel) Steudel ou *Pistacia terebinthus* L. On peut inclure ici un strate lianoïde à *Smilax aspera* L. et *Rubia peregrina* L. jusqu'à 2 m.

- 3) - Strate arbustif inférieur (jusqu'à 1 m.) et herbacé (jusqu'à 0.5 m.): Riche d'éléments du *Rosmarino-Ericion* Br.-Bl. (1931) 1952. Cette richesse peut empêcher l'installation des térophytes (Juste, 1975).
- 4) - Strate à fougères (0.25 m.) et à mousses (2-3 cm.): Très développé et affecté par la sécheresse estivale. *Asplenium onopteris* L. et *Polypodium australe* Fée présentant des valeurs importantes de couverture. Mateo (1983) et Mateo & Figuerola (1984) ont étudié le dynamisme de ces formations à fougères et mousses; elles montrent des tendances scyophiles mais elles permettent une certaine dose d'illumination.

La table 1 montre la composition phytosociologique du "Carrascal".

Matériaux et méthodes.

On a réalisé une étude phénologique des 60 phanérogames les plus représentatives du "Carrascal" - celles qui sont incluses dans la table 1 -. Le territoire fut visité chaque deux semaines; des notes sur l'état de la floraison furent prises sur 10 petites populations - ou parties de la population continue - de chaque espèce du territoire, selon un "transect" de 300 m. de longueur. Le "transect" suivait la cote 450 avec une orientation E-NNE.

D'après chaque échantillonnage on assigna un coefficient de floraison (= fréquence relative du nombre de populations en floraison pour chaque espèce). Etant donné que plusieurs espèces fleurirent plus d'une fois durant l'année 1983, on considéra comme floraison "à l'optimum" celle qui eût le coefficient le plus haut.

On réalisa aussi une étude macroclimatique du territoire durant 1983.

Les données les plus importantes peuvent se rencontrer à Curras & Laguna (1985 et 1986).

Resultats

Composition floristique et phytosociologique.

La table 1 montre la composition floristique du "Carrascal" d'après l'étude selon la méthode de Braun-Blanquet (1950 et 1979) et l'arrangement phytosociologique dans le syntaxon proposé par Costa et al. (1982). Le bynome de chaque taxont en accord avec Tutin et al. (1964-1980), à l'exception de *Coronilla minima* L. subsp. *clusii* (Duf.) Murb.

Selon la composition floristique le territoire est inclus dans le Secteur chorologique Setabense (voir Costa, 1982), qui occupe le Centre et Sud de la province de Valencia et le Nord de celle d'Alicante, au Centre-Est de la Peninsule Ibérique.

Climatologie.

La fig. 4 représente la variation macroclimatique dans le territoire pendant

N° Relevé	1	2	3	4	5
Surface (m ²)	100	100	100	100	100
Pente (°)	45	35	30	35	40
Couverture (%)	80	90	100	100	100
Profondeur du sol (cm.)	25	20	25	20	30

**Caractéristiques de l'Association
et des unités syntaxonomiques
supérieures**

<i>Quercus rotundifolia</i>	2.3	4.4	4.5	5.5	4.4
<i>Rhamnus alaternus</i>	+	1.1	1.1	1.2	1.1
<i>Chamaerops humilis</i>	+1	.	1.2	+	+
<i>Coronilla juncea</i>	1.1	.	+	+	+
<i>Juniperus oxycedrus</i>	+	+	+	+	.
<i>Rubia peregrina</i> subsp. <i>peregrina</i>	.	+	1.1	+	(+)
<i>Lonicera implexa</i>	.	+	+	+	.
<i>Ruscus aculeatus</i>	.	.	+	+	+
<i>Pistacia terebinthus</i>	.	.	+	+	+
<i>Quercus coccifera</i>	(+)	.	(+)	3.3	3.3
<i>Genista valentina</i>	.	1.1	.	1.1	.
<i>Osyris alba</i>	1.1	.	.	.	+
<i>Daphne gnidium</i>	.	1.1	.	+	.
<i>Pistacia lentiscus</i>	.	(+)	1.1	.	+
<i>Asparagus acutifolius</i>	.	(+)	+1	+	(+)
<i>Smilax aspera</i>	.	.	+	+	.

**Différentielles de la sous-association
et de la var. à sols décarbonatés**

<i>Fraxinus ornus</i>	.	(+)	1.2	2.2	1.1
<i>Asplenium onopteris</i>	.	(+)	+	+	2.2

Compagnes

<i>Brachypodium retusum</i>	3.3	3.3	3.3	4.4	3.3
<i>Erica multiflora</i>	2.2	2.2	+	+	1.1
<i>Ulex parviflorus</i>	+	2.2	2.2	1.1	+
<i>Bupleurum fruticescens</i>	+	+	+	1.1	+
<i>Scrophularia sciophila</i>	+	+	.	+	+
<i>Rosmarinus officinalis</i>	2.3	.	.	+	1.1
<i>Polypodium australe</i>	.	+	+	.	2.2
<i>Cistus albidus</i>	+	1.1	.	+	.
<i>Geranium purpureum</i>	.	+1	.	(+)	2.2
<i>Thymus vulgaris</i>	+1	.	.	.	+
<i>Hypericum ericoides</i>	+1	.	.	.	+
<i>Melica ciliata</i> subsp. <i>magnolii</i>	+	.	.	.	+
<i>Carex humilis</i>	.	.	+	+	.
<i>Rubus ulmifolius</i>	.	.	+	.	+

Table 1 — Composition floristique et phytosociologique du "Carrascal". Pour les espèces présentes une fois, voir l'appendice à la fin du texte.

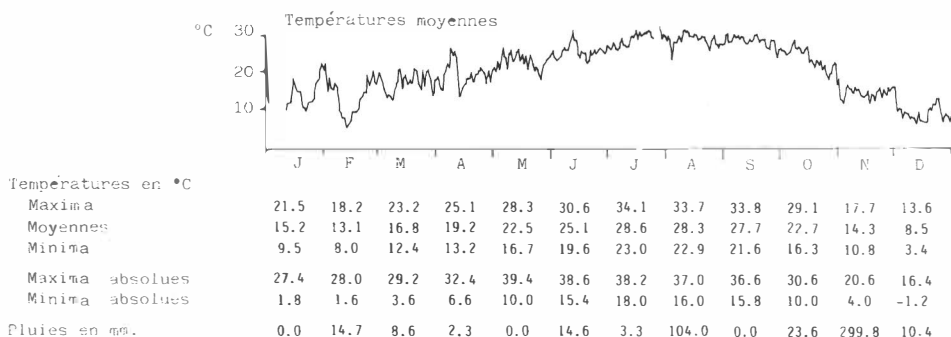


Fig. 4 — Variation journalière des températures moyennes d'après les données du I.N.M. (iné.) et moyennes thermiques et hydriques mensuelles.

l'année 1983. On détache les caractéristiques les plus remarquables des saisons de l'année:

- 1) - Hiver sec mais non froid, à l'exception de Février. Les moyennes des températures furent près de 3°C plus hautes que celles prévues selon les données d'Elías & Ruiz (1977).
- 2) - Printemps très sec avec augmentation progressive des températures.
- 3) - Été long et très chaud jusqu'à la fin d'Octobre. Août et Novembre furent particulièrement humides.
- 4) - Automne courte et humide, avec un fort décroissement des températures.
- 5) - Rentrée de l'Hiver 1983-84, plus froide que l'Hiver 1982-83.

Donc, il y a deux périodes avec des conditions favorables pour le développement des végétaux:

- 1) - La printemps, à températures chaudes mais avec une notable sécheresse.
- 2) - Depuis le début de l'été jusqu'à Septembre avec des températures hautes et une haute réserve hydrique.

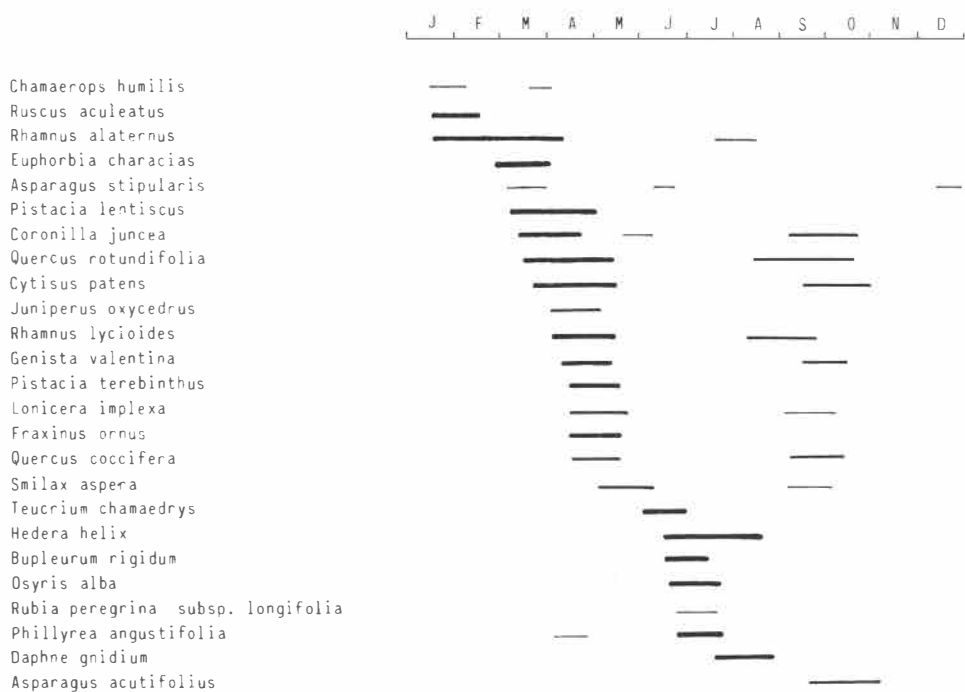
Le début du régime photopériodique LD - jour long, "long day" - s'est produit la deuxième semaine de Mars selon I.N.M. (1984).

Phénologie.

Les figs. 5 - caractéristiques de l'association et des syntaxons supérieurs - et 6 - compagnes - montrent l'évolution des floraisons dans le "Carrascal". On n'a pas indiqué la sporification des fougères, qualitativement différente.

Les floraisons multiples se donnent dans presque un 50% des taxons. Signalons tout particulièrement des floraisons quadruples de *Rosmarinus officinalis* L. et des triples d'*Asparagus stipularis* Forsk., *Erica multiflora* L., *Coronilla juncea* L., *Cistus albidus* L., *Thymus vulgaris* L., *Scrophularia sciophila* Willk. et *Thymus piperella* L. Ces deux dernières sont endémiques de la région valencienne.

La formation végétale présente au moins une espèce à floraison durant chaque mois de l'année. Il n'existent pas de fortes phénophases comme aux climats



Coéfficient de floraison: —:0.80-1.00, —:0.50-0.80, —:0.00-0.50

Fig. 5 — Développement des floraisons pour les espèces caractéristiques (du *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* et des syntaxons supérieurs).

atlantiques centro-européens (voir Larcher, 1979) et aux continentaux de la Péninsule Ibérique (Moreno, 1982); on peut parler d'une gradation progressive des floraisons qui montre la thermicité du climat.

La fig. 7 montre la fréquence absolue d'espèces qui fleurirent chaque mois. Deux optimums sont notables, un en Avril - maximum absolu un autre en Septembre - maximum relatif -. Les figs. 5 et 6 signalent l'optimum saisonnier de chaque taxon. Les fréquences montrées dans la fig. 7 sont analysées à l'aide de la fig. 8, où ces fréquences sont divisées aux groupes des floraisons "à l'optimum" et "au sous-optimum". Chaque fréquence est déterminée per la somme du nombre d'espèces avec chaque type de floraison dans un mois donné.

La floraison "à l'optimum" présente un maximum régulier au cours du printemps - Avril -; la floraison "au sous-optimum", plus irrégulière, présente dans Septembre un maximum défini.

Il y a quelques cas individuels à signaler:

- 1) - *Chamaerops humilis* L.: Le coéfficient de floraison est très bas; il y a une différence de floraison selon le sexe.
- 2) - *Fraxinus ornus* L. et *Pistacia terebinthus* L.: Caducifoliées dont la floraison

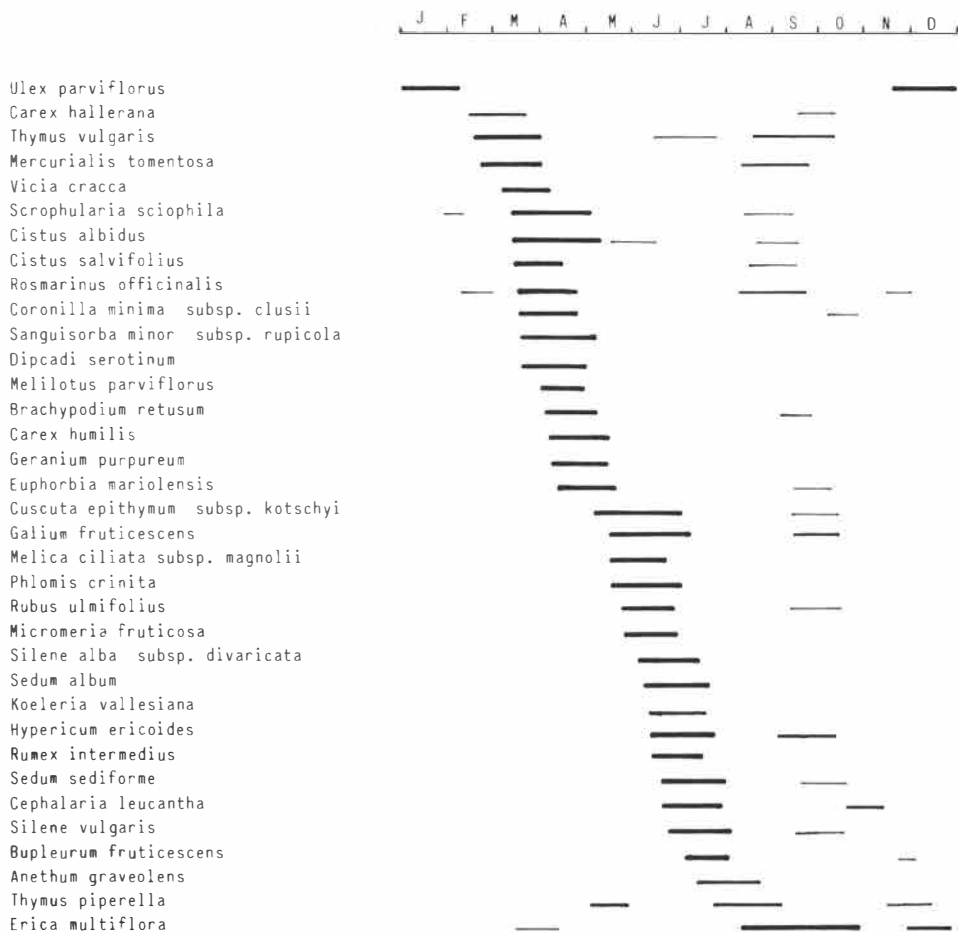


Fig. 6 — Floraison des compagnes de l'association. Pour les coefficients, voir la fig. n° 5.

semble être en relation avec la rentrée du régime photopériodique LD.

Discussion

Le phénomène de la floraison montre un système d'interprétation difficile, car l'interaction des facteurs du milieu avec ces autres d'origine physiologique interne n'est pas bien connue (Larcher, 1979).

Il est difficile d'accepter que le facteur hydrique soit l'unique responsable de la floraison multiple en cas de floraisons "au sous-optimum". La convergence des régimes de la photopériode et de la température joueraient plutôt un rôle fondamental et responsable dans la plupart des cas du développement phénologique. D'autre part, on a encore besoin de réaliser des études profondes sur la physiologie des espèces forestières méditerranéennes.

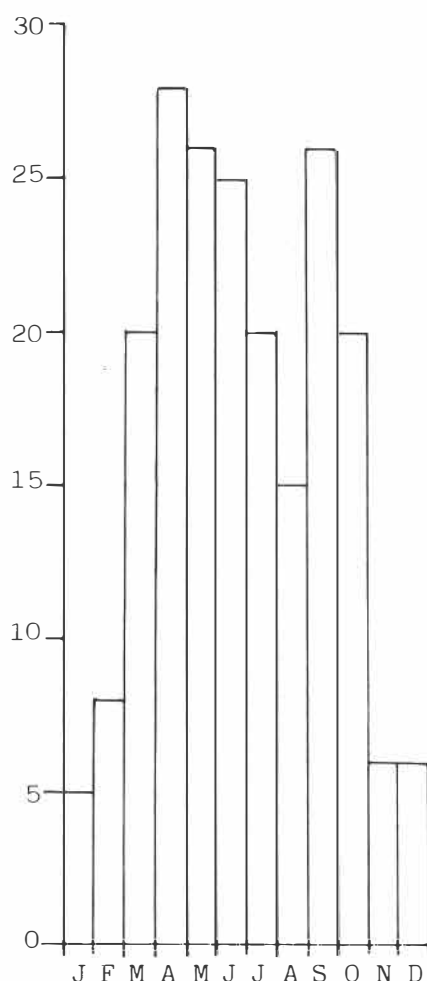


Fig. 7 — Fréquences absolues de floraison (nombre d'espèces).

A notre avis, les facteurs photopériodiques et thermiques - dans cet ordre - donnent un étalon de mesures pour la floraison des taxons méditerranéens; la floraison serait déterminée par la coincidence des régimes photopériodique et thermique qui satisfassent les besoins physiologiques de chaque taxon. Puis les taxons fleuriraient selon les possibilités hydriques du milieu. Les mois à températures croissantes - ou bien chaudes et stabilisées - constituent les périodes optimales de floraison dans le "Carrascal". La charge génétique et phisiologique de chaque espèce pourrait déterminer la floraison indipendement de l'humidité - p.e., les floraisons "à l'optimum" durant Avril dans une période sèche -. Dans ces cas, il est évident que les floraisons sont controlées per l'augmentation des valeurs thermi-

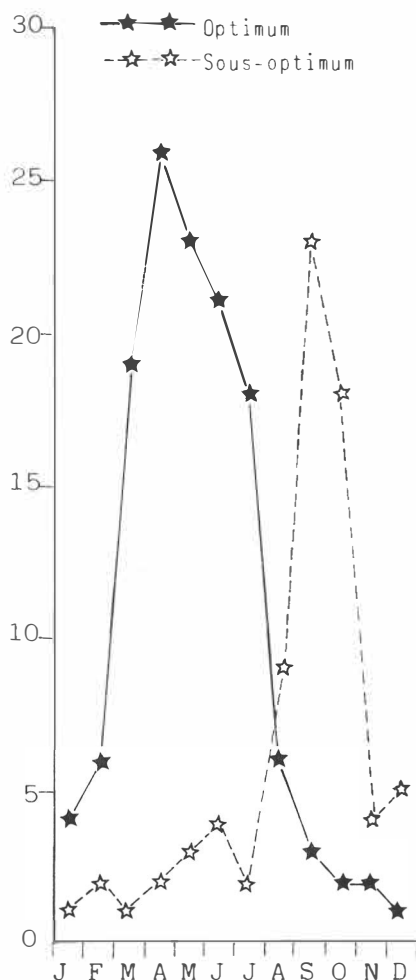


Fig. 8 — Fréquences absolues de floraison "à l'optimum" (étoiles noires) et "sous-optimum" (étoiles blanches).

ques et photopériodiques.

L'importance des facteurs thermiques et hydriques est réfléchi aux mois de l'Automne et de l'Hiver, où la floraison se donnait dans un nombre faible de taxons - p.e., *Ulex parviflorus* L. -. Le reste des taxons semble être très sensible au décroissement thermique et à la rentrée du régime photopériodique SD - jour court, "short day" -.

La floraison "au sous-optimum" donne un maximum pour les mois de la fin de l'été, chez la régime LD et avec des moyennes thermiques hautes. Au cours de l'année, ce type de floraison montre une similitude avec le déroulement des valeurs hydriques; tous les mois avec des précipitations qui dépassent 10 mm ont un

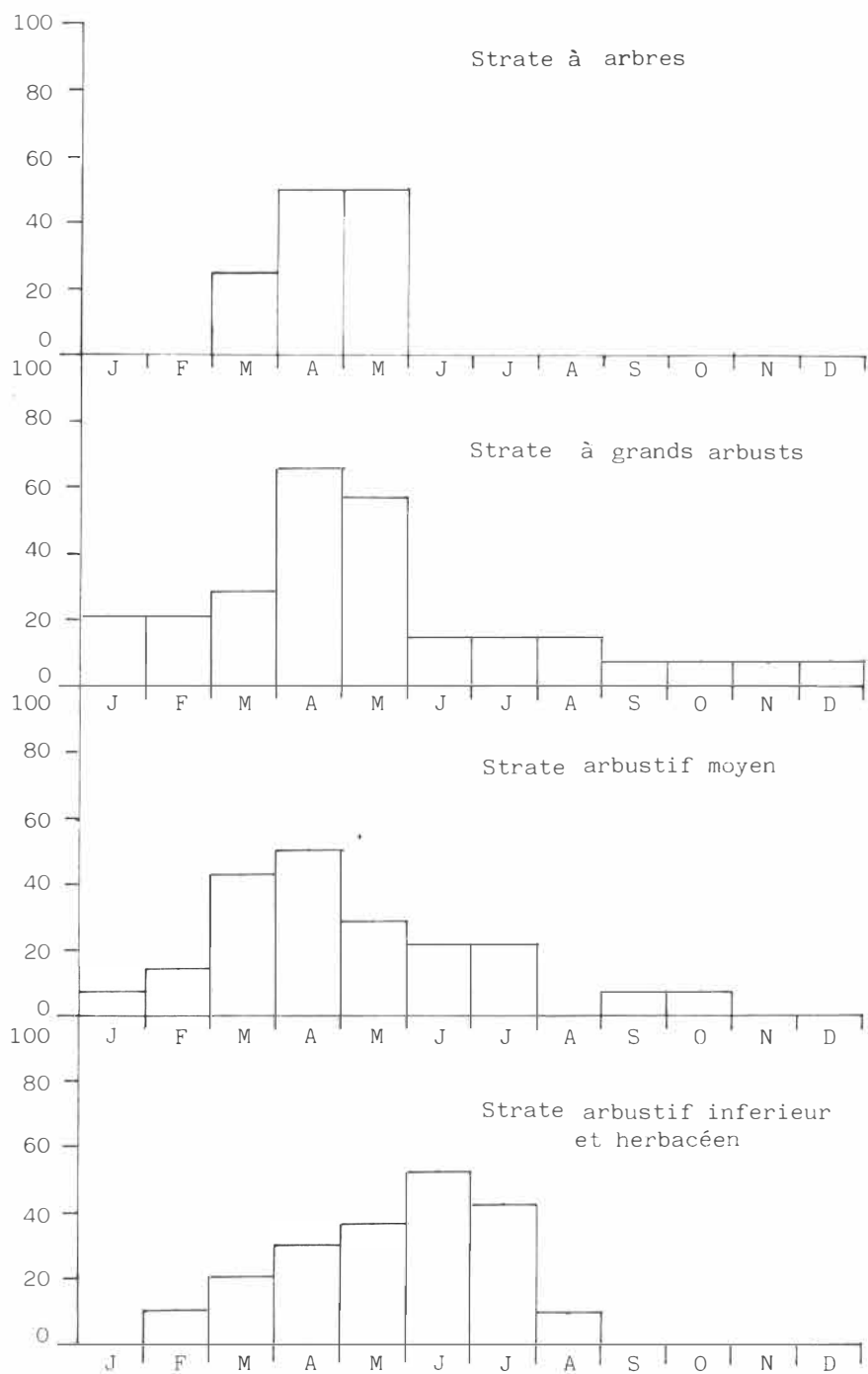


Fig. 9 — Fréquences relatives de floraison (% du nombre d'espèces "à l'optimum") selon les strates du "Carrascal".

maximum relatif de ce type de floraison. Parfois le maximum des fréquences est donnée au mois suivant des pluies. L'importance du facteur hydrique sur la structure de la végétation de la Péninsule Ibérique est remarquée par Allué (1966 et 1983); Guara & Laguna (1985) et Guara et al. (sous-pressé) montrent cette importance dans les territoires valenciens.

Si l'on considère la variation saisonnière de la floraison selon les strates de la communauté végétale, on trouve des déphasages - voir fig. 9 -. Des arbres et des grands arbusts fleurissent au début du printemps tandis que les taxons arbustifs inférieurs et les herbacés fleurissent pendant tout le printemps. La stratification multiple est un "continuum" chez ce maquis et elle ne permet pas d'extraire plus de conclusions; nous considérons que les stratégies phénologiques des éléments ligneux et herbacés montrent une dynamique différentielle, provoquée par les facteurs écologiques déterminants dans chaque strate; les strates supérieures font face au macroclimat, tandis que les éléments herbacés sont plutôt contrôlés par la dynamique du microclimat.

En résumant les résultats, le "Carrascal" montre les phénophases suivantes:

- 1) - Hiver: Températures moyennes en dessous de 15°C. Dominante de floraison: *Ulex parviflorus* L.
- 2) - Printemps, Mars-Avril: Moyennes comprises entre 15 et 20°C. Floraison "à l'optimum" des strates supérieures et des éléments ligneux des strates inférieurs.
- 3) - Printemps, Avril-Juin et rentrée de l'été: Moyennes thermiques entre 20 et 25°C. Floraison "à l'optimum" des éléments herbacés.
- 4) - Été, Juillet-Septembre: Moyennes thermiques entre 20 et 25°C, avec sous-périodes fréquentes où il sont dépassées les 25°C. Floraison "à l'optimum" des éléments les plus exigeants en besoins thermiques - *Daphne gnidium* L., *Asparagus acutifolius* L., *Thymus piperella* L. - et des éléments sans besoins de froid mais avec une tendance à la rentrée du régime SD - *Erica multiflora* L. -. Haute fréquence des floraisons "au sous-optimum" après les pluies, vers la rentrée de l'Automne.
- 5) - Automne: Décroissement brusque des moyennes thermiques; régime photopériodique SD; arrêt des floraisons de toutes les espèces et début de la floraison pour celles qui ont l'optimum d'Hiver.

Ces données sont très significatives si l'on compare avec les résultats obtenus par Setchell (voir Braun-Blanquet, 1979) chez le "chaparral" californien. Cette convergence phénologique - phénophases chaque 5°C - est une nouvelle démonstration de l'adaptation des végétaux méditerranéens aux facteurs du milieu, et qui vient d'être montrée par Shmida (1981) et Quézel & Taylor (1984) en relation avec ses études structurales.

Les résultats mettent en évidence la relation entre le climat et la floraison; les températures printanières et le régime LD peuvent provoquer la floraison de la plupart des espèces; les températures plus hautes dans le même photopériodique peuvent provoquer de nouveau la floraison - cette fois "au sous-optimum" - mais à l'aide de fortes précipitations estivales. Les deux saisons optimales pour le

déroulement végétatif se manifestent aussi dans le développement des floraisons dans le *Rubio longifoliae* - *Quercetum rotundifoliae fraxinetosum orni*. Des résultats semblables mais plus faibles sont donnés dans le travail de Bourrelly et al. (1983). Loisel et Vignes (1983 et 1984) montrent aussi quelques exemples d'associations avec saisons optimales comme celles du "Carrascal", mais celles-là ont le maximum automnal très faible par rapport à la nôtre. Nous n'avons pas trouvé non plus de renseignements au sujet de travaux de phénologie des espèces méditerranéennes ibériques comme ces de Moreno (1982), Herrera (1984) ou Martín & Escarré (1980), où l'on signale la floraison simple - très longue au cas d'*Osyris quadripartita* pour l'Andalousie -. Il est possible que le maximum relatif automnal des travaux de Loisel et Vignes (ops. cit.) soit donné par la somme de la floraison des espèces de floraison unique automnale et pas par l'existence d'une floraison multiple. Pour les autres aires à climat méditerranéen du Monde, les travaux ne signalent pas de cas de floraison multiple fréquente (Di Castri & Mooney eds. 1973; Di Castri et al., 1981; Kruger, 1979; Miller, 1985; Reader, 1984; Arroyo et al., 1981).

Selon ces données la floraison automnale "au sous-optimum" serait plutôt un mécanisme adaptatif de quelques espèces méditerranéennes - surtout des éléments ligneux - pour tirer le plus grand profit de la variabilité du facteur hydrique. L'existence des deux saisons optimales par rapport du facteur limitant - l'hydrique - permet deux phases de croissance aux éléments ligneux (voir Liphshitz et al., 1981, 1984 et 1985) et ces deux phases pourraient être utilisées aussi pour la floraison. Ici on met en relation l'hypothèse d'une convergence des stratégies végétatives et florales avec le climat. Nous ne voudrions pas écarter une deuxième possibilité, selon laquelle la floraison multiple ne fût qu'une réponse des végétaux au "stress" hydrique. Selon cette hypothèse, la plus grande partie des taxons ligneux fleuriraient par deuxième ou troisième fois - toujours après la pluie en saison sèche - en montrant un mécanisme de sûreté pour la continuité de l'espèce. Il s'agirait d'une stratégie situation de crise, où la fin la plus importante serait la production des semences. Aucune de ces deux hypothèses est écartable, et il est possible qu'elles soient liées évolutivement; de toute façon, on peut voir une convergence phénologique notable, où la floraison est mise en rapport avec la variabilité du climat, et en soulignant l'importance de la réponse de la plante et de l'association végétale à la variation du facteur écologique le plus effectif.

Conclusions

Le *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* Costa, Peris & Figuerola 1982 est caractérisé phénologiquement par l'existence de deux grands groupes de floraison:

- 1) - Floraison "à l'optimum", avec le maximum vers Avril.
- 2) - Floraison "au sous-optimum", avec le maximum vers Septembre, après les hautes valeurs pluviométriques d'Août.

Plus du 50% des taxons développe des floraisons multiples; dans ces cas, les floraisons au "sous-optimum" sont subordonnées à niveaux pluviométriques supérieurs aux 10 mm/mois.

La floraison des strates composés par des éléments ligneux se donne en Mars-Avril-Mai, tandis que celle du strate herbacé se développe entre Mai et Septembre.

Resumé. On étudie la floraison du *Rubio longifoliae-Quercetum rotundifoliae fraxinetosum orni* Costa, Peris et Figuerola 1982 pendant l'année sèche 1983, au "carrascal" du Collado Blanco (Valencia, Espagne). La forêt est caractérisée par une haute fréquence des floraisons multiples - plus une floraison annuelle. La floraison "à l'optimum" (la plus haute fréquence dans chaque taxon) est printanière tandis que la floraison "au sous-optimum" (fréquence basse) est automnale et très relationnée avec la pluviométrie.

Remerciements

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Appendice

Espèces présentes une fois (appendice de la table n° 1)

DE L'ASSOCIATION ET DES UNITÉS SUPÉRIEURES: Relevé n° 1: *Phillyrea angustifolia*, 2.2; *Asparagus stipularis* +. Relevé n° 2: *Bupleurum rigidum* +.1. Relevé n° 3: *Euphorbia characias*, +. Relevé n° 4: *Teucrium chamaedrys*, +. Relevé n° 5: *Rhamnus lycioides*, +.; *Silene alba* subsp. *divaricata*, +.

DIFFÉRENTIELLES: Relevé n° 3: *Cytisus patens*, +. Relevé n° 4: *Hedera helix*, +

COMPAGNES: Relevé n° 1: *Cephalaria leucantha*, +; *Sedum album*, +; *Sedum altissimum*, +; *Dipcadi serotinum*, +; *Cuscuta epitimum* subsp. *kotschii*, +; *Carex hallerana*, +; *Mercurialis tomentosa*, +; *Phlomis crinita*, +. Relevé n° 2: *Silene vulgaris*, +; *Sanguisorba minor* subsp. *rupicola*, +. Relevé n° 3: *Anethum graveolens*, +. Relevé n° 4: *Thymus piperella*, +. 1; *Cistus salvifolius*, +; *Vicia cracca*, +; *Euphorbia mariolensis*, +. Relevé n° 5: *Coronilla minima* subsp. *clusii*, +; *Melilotus parviflorus*, +; *Galium frutescens*, +; *Koeleria vallesiana*, +.

DONNÉES DE L'ANALYSE DU SOL. (Méthodes selon Duchaufour, 1965).

Profil et horizons: A0, 2-3 cm; Ah, 15-20 cm; C, roche dolomitique.

Humidité: 9.45%

Texture: 67.32% sable; 15.30% argile; 17.38% limon.

Carbonates: 0.72%. Composition: 45.55% Co₃Ca, 54.45% Co₃Mg2

Matière organique: 25.01%

Conductivité: 0.308 mmhos/cm, 25°C.

pH: 7.16

Couleur Münsell: sec: 7.5 YR 3/2, brun foncé; humide: 5 YR 2.5/2, brun rougeâtre foncé.

Profondeur moyenne du sol: 20 cm.

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Authors' addresses:

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|-----------|--|
| R. Currás | Cátedra de Botánica. Facultad de Ciencias Biológicas. Universidad de Valencia. c/ Dr. Moliner, 50. Burjasot. 46100 Valencia. España. |
| E. Laguna | Attaché de Recherches par la Consellaria de Cultura, Educació i Ciència de la Generalitat Valenciana. |

SPATIAL AUTOCORRELATION ANALYSIS: COMPUTER PROGRAM AND EXAMPLES OF APPLICATION WITH DIFFERENT DATA OF GRASSLAND VEGETATION UNDER A NATURAL REFORESTATION PROCESS IN THE KARST NEAR TRIESTE

Paola GANIS

Keywords: autocorrelation, gradient, grasslands, grids, hierarchy, Karst, pattern, transects, vegetation.

Abstract. A program in FORTRAN 77 for spatial pattern based on the methods of nearest-neighbor and autocorrelation is presented. It has been used with the option for autocorrelation to analyse the spatial pattern of 120 species and other variables as life-growth forms, chorological elements and classes of environmental variables, along transects from open grasslands to groups of trees (NR) in the Karst area near Trieste. The results proved that both the species and the other variables show significant pattern. Particularly a high degree of significance has been found for the variables of higher hierarchical meaning than species and especially for the classes of environmental variables. The number of entities with significant pattern increases in function of the length of the transect. The results prove that along the transect there is a composite ecological gradient which produces significant changes of vegetation pattern at different hierarchical levels, both structural and chorological.

Introduction

Spatial pattern analysis of vegetation has been made by using several methods considering simultaneously many species as was suggested by David (1971a), Pielou (1975), Juhasz Nagy (1976), Feoli et al. (1980), Juhasz-Nagy & Podani (1983) or analysing single species (Goodall, 1974; Greigh-Smith, 1979; Galiano, 1982; Ford & Renshaw, 1984). It looks that the methods of autocorrelation, widely known in Geography (Ebdon, 1977), have been rarely applied in plant ecology (e.g. David, 1971b). A program in FORTRAN 77 for spatial pattern analysis, based on the method of nearest neighbor and the method of autocorrelation, has been developed. The listings are presented in the Appendix. The aim of the present paper is to show how to compare, by the program, the spatial pattern of species, life-growth forms, chorological elements and classes of environmental variables, as defined by the ecological indicator values of Landolt (1977), along transects in grasslands under a natural reforestation process in the Karst region near Trieste.

The process in such region has been studied by different points of view by Lausi, Pignatti & Poldini (1967), Feoli & Feoli Chiapella (1979), Feoli et al. (1980), Feoli & Scimone (1982), Poldini & Favretto (1985).

The use of variables of higher hierarchical meaning than species may allow to

investigate into vegetation patterns at more general level than that of species. Notwithstanding biology is "a very hierarchical science" (see Thornley, 1979; Allen & Starr, 1982) the discussion on the hierarchical processes for vegetation analysis started only recently by Feoli (1984), Feoli & Scimone (1985) and Orlóci et al. (1986). In such processes the species are considered only as carrier of the biological information useful to understand the relationships between chorology, structure and ecology of vegetation (see Feoli & Ganis, 1985).

Program PATTERN

The program PATTERN consists of a root program calling four subroutines (PIUVIC, CORBIN, CORVAL and CORPUN) each performing a different technique for the measurement of pattern. PIUVIC analyses the pattern by the nearest-neighbour technique, CORBIN calculates the spatial autocorrelation for binary data and CORVAL for ordinal and continuous data related to areas, finally CORPUN computes the spatial autocorrelation for ordinal and continuous data related to points. The program PATTERN is written in Fortran 77 for a Cyber 170-730.

a) Nearest-neighbour analysis (subroutine PIUVIC)

This technique has been developed by plant ecologists (Clark and Evans, 1954). It consists in calculating for each point of a set of points the distance to its nearest-neighbour and then in calculating the mean of the distances. It matters to underline that the number of nearest-neighbour distances is always the same as the number of the considered points. It means that if two points are each one the nearest-neighbour for the other one, their distance must be added twice in the sum of all the distances. The mean nearest-neighbour distance is the observed index (D_{obs}) that is compared with the expected mean nearest-neighbour distance for the different types of spatial arrangements of points.

For a random arrangement the theoretical mean nearest-neighbour distance (D_{ran}) is given by the equation 1) calculated by Clark and Evans (1954) (symbolism follows Ebdon, 1981).

$$1) \quad D_{ran} = \frac{1}{2\sqrt{p}}$$

where p is the density of points per unit area. We remember that the area calculated in the program is the one given by a rectangle which encloses all the points as closely as possible. The area is calculated in the same units as the distances between the points.

For a uniform pattern, where the greatest dispersion of the points is realized, the expected mean-nearest-neighbour distance (D_{dis}) is given by the equation 2).

$$2) \quad D_{dis} = \frac{1.07453}{\sqrt{p}}$$

Finally, in the third type of pattern (clustered) the points are as close as possible to the other points, and therefore superimposed. In this case the mean nearest-neighbour distance is zero. The random pattern type is considered to have intermediate values between the two extreme types: clustered and dispersed.

The nearest-neighbour index (R) is given by the following equation:

$$3) \quad R = D_{obs}/D_{ran}$$

It can be seen that the index R is equal to 1.0, when the observed index is equal to the expected mean nearest-neighbour distance for a random arrangement of points; if the index R gets near the value zero, it indicates a clustered pattern and if it is getting near the value D_{dis}/D_{ran} it indicates a dispersed pattern.

It is possible to value how the pattern is significantly clustered or dispersed looking at the tables of critical values of nearest-neighbour index R (see Edmon 1976).

Another way to test the significance of results from nearest-neighbour analysis is to use the statistic test c given by equation 5) that is similar in form to Student's t and has a normal distribution. Also in this case, positive value of c indicate a dispersed pattern and negative values a clustered one.

The null hypothesis of random pattern can be rejected if the value c is greater or less than the appropriate critical value related to the chosen significance level deduced from the tables of critical values of a standard normal deviate.

$$4) \quad SE = \frac{0.26136}{\sqrt{np}}$$

$$5) \quad c = (D_{obs} - D_{ran})/SE$$

n = the number of the points.

SE = standard error of the mean nearest-neighbour distance.

The subroutine PIUVIC requires in input:

on tape 1 - a) the variable label

b) the numbers of the points and the number of the considered axes

c) for each point the cartesian co-ordinates relatives to two or more axes. The co-ordinates are given in free format, each point in a new row.

If the axes are more than two, the subroutine only computes for each point its nearest-neighbour distance. If the points are in a bi-dimensional surface, the subroutine completes the nearest-neighbour analysis calculating the index R and the test c too. Notwithstanding Clark & Evans (1979) extend the method to test C for more than 2 dimensions, the problems related to the definition of density suggest to use the Moran's I (CORPUN) for testing the pattern in n dimensional spaces.

b) Spatial autocorrelation

The spatial autocorrelation introduced by Cliff & Ord (1973, 1981) allows to measure the variation of a variable through space. In this analysis the basic idea is that if the values of a variable in adjacent areas are similar and if they are very dissimilar to those of distant areas then there is a high spatial autocorrelation and therefore a high heterogeneity.

Subroutine Corbin

This subroutine computes the spatial autocorrelation for binary data on areas. It is called to see if the spatial arrangement of areas with two different scores (a_1 , a_2) is or not at random. In this case the observed index (I_{obs}) is simply the number of joins between areas of different scores. This index is compared with the expected value for a random pattern. There are two forms of null hypothesis for the significance test. The former (free sampling) is applied only when the probability of the scores is known a priori; the latter (non-free sampling) is used when the probability is unknown.

For the first form the expected value (I_{exp}) and the standard deviation (S) are given by 6) and 7), and, for the second form, the same values are given by 8) and 9).

$$6) \quad I_{exp} = 2 J p q$$

$$7) \quad S = \sqrt{[2 J + \sum L(L-1)] p q - 4 [J + \sum L(L-1)] p^2 q^2}$$

$$8) \quad I_{exp} = \frac{2 J a_1 a_2}{n(n-1)}$$

$$9) \quad S = \sqrt{I_{exp} + \frac{\sum L(L-1) a_1 a_2}{n(n-1)} + \frac{4 [J(J-1) - \sum L(L-1) a_1(a_1-1) a_2(a_2-1)]}{n(n-1)(n-2)(n-3)} - I_{exp}^2}$$

$$10) \quad z = (I_{obs} - I_{exp})/S$$

J = total number of joins in the study region

p = probability that an area will have the score a_1

q = probability that an area will have the score a_2 ($p + q = 1.0$)

a_1 = the number of areas with a_1

a_2 = the numbers of areas with a_2

$n = a_1 + a_2$ = the total number of areas in the study region

L = the number of joins between an area and contiguous areas ($L = 2J$).

The statistic z is calculated by the equation 10) and is used as test. It follows a normal distribution, so as for the test c of the nearest-neighbour analysis, in order to

test the significance, it needs to examine the appropriate critical values of the tables of a standard normal deviate.

The areas must be labelled by different ordinal numbers. The subroutine CORBIN requires in input:

- from tape 1- a) for each join the numeric labels of the contiguous areas.
b) for each area, the number of joins between that area and all contiguous areas.
The inputs a) and b) are in free format.
- c) the input format for the table of variables (enter by rows)
- d) the output format for the variables. If missing the variables are not printed.
- from tape 2- the labels of the variables (up to 80 characters); if missing the subroutine numbers automatically the variables.
- from tape 3- for each variable its value inside each area.
- from the keyboard - the numbers of the areas, the number of the joins, the option choosing the null hypothesis (1 = free-sampling, 2 = non-free sampling). If the null hypothesis of free sampling is selected, the a priori probability must be given in input.

Subroutine Corval

This subroutine calculates the spatial autocorrelation for ordinal or interval data on areas.

The observed index (*I obs*) has been proposed by Moran (1950). It is described in equation 11). Two forms of null hypothesis apply: the hypothesis of normality in which the observed values of the variables are drawn at random from a normally distributed population, and the hypothesis of randomization that does not consider any kind of distribution.

The equation for the expected value of index (*I exp*) is given by 12), and the ones for the standard deviation under the first and the second null hypothesis are presented in 13) and 14) respectively. In both cases the test *z* is the same as that used in the spatial autocorrelation for binary data (equation 10). It may be worth noting that negative values of the index indicate dispersion pattern, whereas positive value imply clustering.

$$11) \quad I_{obs} = \frac{n \sum_{(ij)} (x_i - \bar{x})(x_j - \bar{x})}{J \sum (x - \bar{x})^2}$$

$$12) \quad I_{exp} = - \frac{1}{n - 1}$$

$$13) \quad S = \sqrt{\frac{n^2 J + 3 J^2 - n \sum L^2}{J^2 (n^2 - 1)}}$$

$$14) \quad S = \sqrt{\frac{n[J(n^2 + 3 - 3n) + 3J^2 - n\Sigma L^2 - k[J(n^2 - n) + 6J^2 - 2n\Sigma L^2]]}{J^2(n-1)(n-2)(n-3)}}$$

$$15) \quad s = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n}}$$

$$16) \quad k = \frac{\Sigma(x - \bar{x})^4}{n s^4}$$

n = number of areas in the study region

J = number of joins

x = a ordinal or interval value for an area

$\bar{x}$ = the mean of all the values of the variable x

x_i and x_j = the values for two adjacent areas

L = number of areas to which an area is joined

k = kurtosis of the variable x .

The areas must be labelled by different ordinal numbers. The subroutine CORVAL requires in input:

from tape 1 - a) for each join the numeric labels of the adjacent areas.

b) for each area the number of joins between that area and all contiguous areas.

The inputs a) and b) are in free format.

c) the input format for the table of variables disposed in rows.

d) the output format for the variables; if missing the variables are not printed.

from tape 2 - the labels of the variables (up to 80 characters); if missing the subroutine numbers automatically the variables.

from tape 3 - for each variable its value inside each area.

from the keyboard - the numbers of areas, the numbers of joins, the option selecting the null hypothesis (1 = normality, 2 = randomization).

Subroutine Corpun

This subroutine calculates the spatial autocorrelation for variables in ordinal or interval, ratio scales associated to points.

It calculates the observed index (I_{obs}) as a revised version of Moran's one (equation n. 17) based on the distances between the points. For n points there will be $p = n(n-1)/2$ possible pairs of points. If such distances are not given from external tape (tape 4), they are computed within the program as was done by Feoli & Ganis (1986). The expected value of index (I_{exp}) is the same of the previous analysis (equation 12). In equation 18) and 19) the standard deviation under the hypothesis of normality and randomization are respectively given. The test z (equation 10) is the same of the one already described for the spatial autocorrelation

for binary data.

$$17) \quad I_{obs} = \frac{n \sum_{(p)} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{(\sum_{(p)} w_{ij}) \sum (x - \bar{x})^2}$$

$$18) \quad S = \sqrt{\frac{n^2 A + 3 B^2 - n C}{(n^2 - 1) B^2}}$$

$$19) \quad S = \sqrt{\frac{n[(n^2 + 3 - 3n)A + 3B^2 - nC] - k[(n^2 - n)A + 6B^2 - 2nC]}{(n-1)(n-2)(n-3)B^2}}$$

w_{ij} = the reciprocal of the distance between the point i and j . It is a weight assigned to the relationship between two points.

k = kurtosis of the variable x

x_i and x_j = the values for the points i and j

$\bar{x}$ = the mean of all the values of the variable x

$A = \sum_{(p)} w_{ij}^2$

$B = \sum_{(p)} w_{ij}$

$C = \sum_i (\sum_j w_{ij})^2$

The subroutine CORPUN requires in input:

from tape 1 - a) for each point the cartesian co-ordinates relatives to two or more axes. This input is given in free format, each point in a new row.

b) input format for the table variables disposed in rows.

c) output format for the variables; if missing the variables are not printed.

If the lower triangular distance matrix is read from tape 4, these inputs from tape 1 are missing.

from tape 2 - the labels of the variables (up to 80 characters); if missing the subroutine numbers automatically the variables.

from tape 3 - for each variable, the value in each point.

from tape 4 - a) the input format for the lower triangular distance matrix.

b) the lower triangular distance matrix computed outside this program. In this case the subroutine does not read the point co-ordinates.

c) input format for the table variables disposed in rows.

d) output format for the variables; if missing the variables are not printed.

from the keyboard - the number of the points, the number of the axes, the option selecting the null hypothesis (1 = normality; 2 = randomization), the option (= 1) indicating the distance matrix coming from tape 4.

Examples

a) Data

The relevés for pattern description have been performed by a grid of 1 square

NR

8				
				7
3	3		3	
			25	12
1				
	5		7	10
30	30	7	5	18
30	30	8	25	15
10	7	5		25

$z=7.527$

Fig. 1a — Example of a transect of 3 relevés each one consisting of a grid of 1 square metre subdivided in 25 quadrats. The first grid is the nearest the NR. For each quadrat the percentage of cover values of the single specie *Stachys officinalis* ssp. *serotina* are reported. For this arrangement the test z has a very significant value: 7.527.

NR

18				
			7	7
		15	12	
	7		8	
3	3		11	11
			5	3
		4		10
			8	12
	10		15	34
1	8			10
13	10	7	14	30
30	48	25	22	28
35	46	28	45	23
23	18	30	25	46

$z=10.308$

Fig. 1b — Example of the arrangement of the European chorological element in the same transect as in Fig. 1a. Inside the grids, the value represent the cover sum of all the european species in each quadrat. One of them is the *Stachy officinalis* ssp. *serotina*, the single arrangement of which is given in Fig. 1a. For this pattern the test z has a higher value: 10.308.

metre subdivided into 25 quadrats with side of 20 cm. This size has been used because 20x20 cm is approximately the maximal surface occupied by a plant of *Bromus erectus* Huds., or *Carex humilis* Leys. in the grasslands under study. For each quadrat the percentage of cover values of all the species have been considered. The relevés have been made along transects, 24 in total, starting from the centre of the grasslands and running to the groups of trees and shrubs called nuclei of reforestation (NR, Feoli e Feoli Chiapella, 1979). In total 120 species, included in 17 life-growth forms, 15 chorological elements and 48 classes of environmental variables have been considered. The length of the transects varies from 1 to 5 metres depending on the degree of closeness of the NR around the grasslands: short transects correspond to short distances between the NR, while long transects have been possible only in open grasslands. The last releve of the transect is always close to the trees of NR (such as *Ostrya carpinifolia* Scop., *Fraxinus ornus* L., *Quercus pubescens* Willd., *Quercus petraea* (Matt.) Liebl., *Prunus mahaleb* L., *Acer campestre* L., *Acer monspessulanum* L.) or to the shrubs of *Crataegus monogyna* Jacq., *Juniperus communis* L. and *Cotinus coggygria* Scop.. These often form a sort of belt around the NR.

b) Methods

The transects have been divided in 4 groups depending on their length: the first group has only a single relevé, the second two, the third three, the fourth four or five relevés.

The autocorrelation method has been applied for each transect and for each relevé by considering the single species (Figure 1a), the single life-growth forms, chorological elements (Figure 1b) and the classes of ecological variables defined by indicator values following Landolt (1977). Program FUSAF (Ganis, 1985) has been used to condense the values of the species into the other variables of higher hierarchical meaning. The analysis of spatial pattern has been done by program AUTOCOR. Among the methods was selected the one based on Moran's (1950) index (option CORVAL).

The method has been described and widely commented by Cliff and Ord (1973, 1981). The hypothesis of randomization has been chosen for the significance of the Moran's index: the test z is significant at 0.05 level, or more, when equal or greater 1.960.

c) Results

The analysis has shown that life-growth forms, chorological elements and classes of environmental variables have on the average a more significant spatial pattern than that of the species. In Table 1 some statistics of the observed entities (species and other categories) are reported for each group of transects. It can be seen that all the values increase with the increasing of the length of the transect. The relationship may be expressed by a function of the type $y = a(1 - \exp(-bx))$, however also a linear function fits efficiently the relationship, at least within the length of 5 metres. The increment is higher for ecological classes followed in order by

Species	I	II	III	IV
1	23.0	34.0	34.1	39.3
2	5.8	13.5	19.8	24.3
3	25.9	41.8	57.3	61.3
4	8.8	4.8	9.4	7.8
5	2.843	3.780	4.658	5.299
Growth forms				
1	6.3	8.0	9.0	9.0
2	1.7	4.3	5.6	6.0
3	26.8	55.5	63.2	66.9
4	14.6	21.9	17.7	10.1
5	2.550	4.017	4.478	5.861
Chorological elements				
1	9.4	10.0	10.3	9.3
2	3.0	5.3	7.8	7.7
3	31.9	51.7	74.9	82.2
4	15.1	13.6	15.2	5.9
5	2.676	3.881	4.867	5.835
Classes of species on the basis of the ecological indicators values				
1	25.4	26.3	27.2	27.7
2	7.6	14.3	23.1	26.3
3	30.0	54.7	84.9	95.2
4	11.1	16.1	8.6	2.0
5	3.138	4.086	5.077	6.421

Tab. 1 — Relevant parameters for each considered entity (species or category of species) and for each of the 4 groups of transects (I, II, III, IV). The rows indicate: 1) the mean number of observed entities; 2) the mean number of entities with significant pattern; 3) the mean percentage of entities with significant pattern; 4) the standard deviation of 3); 5) the mean of significative values of z.

$$\begin{array}{ll}
 1) y = 15.40 x + 6.46 & 3) y = 20.74 x + 6.60 \\
 2) y = 17.20 x + 8.44 & 4) y = 24.53 x + 3.90
 \end{array}$$

Tab. 2 — Equations of the regression lines for the percentages of the variables with significant pattern in function of the lenght of the transects.

chorological elements, life-growth forms and species. Table 2 presents the equations of the regression lines for the precentages of significant variables in function of the lenght of the transects. The slopes of the regression lines are significantly different at better than 5% for species and classes of environmental variables and for life-growth forms and again the classes of environmental variables.

The autocorrelation analysis applied for single releves has given similar results as the short transects of the first group: on the average, only few entities have proved a significant pattern.

This means that the effects of the compositional gradient along the transects are

better detectable if at least the length of two metres of grassland are considered.

The fact that the variables of higher hierarchical meaning have shown more significant patterns than species, suggests that the randomness associated with the dispersion of the species on the ground is higher than that associated with the other variables.

This can be explained by the "rarity" of the great part of them; among the 120 species only about 25-30% may be considered abundant species. In other words, the idea that the spatial pattern is a matter of a phenomenon at higher hierarchical levels than species should be supported and furtherly investigated.

Also in this study the chorological elements resulted more sensitive with respect to environmental changes than the life-growth forms (see Feoli & Ganis, 1986). This fact suggests that, in studying the problem of coexistence of plant species (see Shmida & Ellner, 1984) the chorology should also be considered because carrier of those historical information which can contribute to explain the presence of a set of species in a given site.

EXAMPLE OF INPUT FOR SUBROUTINE PIUVIC

From Tape 1

A) Prima variabile

B) 8,2

C) 1,7

1,8

2,9

4,9

6,8

3,7

5,9

8,8

A) SECONDA VARIABILE

B) 5,4

C) 3, 7, 9, 10

5, 1, 7, 4

0, 3, 6, 8

5, 5, 1, 8

6, 6, 3, 4

EXAMPLE OF INPUT FOR SUBROUTINE CORBIN OR CORVAL

FROM TAPE 1

FROM TAPE 2

FROM TAPE 3

1)	1,2	BROMUS ERECTUS	90 90 80 95 80 00 00 00 00 00
	2, 3	CAREX HUMILIS	25 00 35 00 25 00 35 00 30 00
	3, 4	FESTUCA RUPICOLA	60 80 00 00 00 70 75 00 00 00
	4, 5		
	1, 6		
	2, 7		
	3,8		
	4, 9		
	5, 10		
	6, 7		
	7, 8		

8, 9
 9, 10
 1, 7
 2, 6
 2, 8
 3, 7
 3, 9
 4, 8
 4, 10
 5, 9
 B) 3, 5, 5, 5, 3, 3, 5, 5, 5, 3
 C) (10F3.0)
 D) ((10X, 5F4.0)/)

EXAMPLE OF INPUT FOR SUBROUTINE CORPUN
 FROM TAPE 1 FROM TAPE 2

	FROM TAPE 1	FROM TAPE 2	FROM TAPE 3
A)	1, 7	BROMUS ERECTUS	90 90 80 10 10 10 15 20
	1, 8	CAREX HUMILIS	25 90 90 90 25 60 60 60
	2, 9	FESTUCA RUPICOLA	45 35 25 60 35 45 50 55
	4, 9		
	6, 8		
	3, 7		
	5, 9		
	8, 8		
B)	(8F3.0)		
C)	(10X, 8F4.0)		

EXAMPLES OF OUTPUTS

ANALISI DEL VICINO PIÙ PROSSIMO

LIVELLI DI SIGNIFICATIVITÀ		0.1	0.05	0.01	0.005	0.001
TEST A UNA CODA	Z =	1.282	1.645	2.326	2.576	3.090
TEST A DUE CODE	Z =	1.645	1.960	2.576	2.813	3.291

1 PRIMA VARIABILE

N. PUNTI = 8 N. ASSI = 2

PUNTO	PUNTO PIÙ PROSSIMO	DISTANZA
1	2	1.0000
2	1	1.0000
3	2	1.4142
4	7	1.0000
5	7	1.4142
6	1	2.0000
7	4	1.0000
8	5	2.0000

DISTANZA MEDIA OSSERVATA = 1.3536
 DISTANZA ATTESA RANDOM = .6614
 DISTANZA ATTESA DISPERSA = 1.4215
 INDICE DEL VICINO PIÙ PROSSIMO R = 2.0464
 TEST STATISTICO C = (D. OSS-D.RAN)/SE = 5.6619

2 SECONDA VARIABILE

N. PUNTI = 5 N. ASSI = 4

PUNTO	PUNTO PIÙ PROSSIMO	DISTANZA
1	3	6.1644
2	5	6.4807
3	1	6.1644
4	5	4.6904
5	4	4.6904

AUTOCORRELAZIONE SPAZIALE PER DATI BINARI SU AREE
N. AREE = 10 N. CONFINI = 21
IPOTESI NULLA NON VINCOLATA

LIVELLI DI SIGNIFICATIVITÀ		0.1	0.05	0.01	0.005	0.001
TEST A UNA CODA	Z =	1.282	1.645	2.326	2.576	3.090
TEST A DUE CODE	Z =	1.645	1.960	2.576	2.813	3.291

1	BROMUS ERECTUS					
	90. 90. 80. 95. 80.					
	0. 0. 0. 0. 0.					
	INDICE OSS.	INDICE ATT.	TEST Z			
	13.0000	11.6667	.7483			

2	CAREX HUMILIS					
	25. 0. 35. 0. 25.					
	0. 35. 0. 30. 0.					
	INDICE OSS.	INDICE ATT.	TEST Z			
	13.0000	11.6667	.7483			

3	FESTUCA RUPICOLA					
	60. 80. 0. 0. 0.					
	70. 75. 0. 0. 0.					
	INDICE OSS.	INDICE ATT.	TEST Z			
	4.0000	11.2000	-4.1451			

AUTOCORRELAZIONE SPAZIALE PER DATI QUANTITATIVI SU AREE
N. AREE = 10 N. CONFINI = 21
IPOTESI NULLA DI RANDOMIZZAZIONE

LIVELLI DI SIGNIFICATIVITÀ		0.1	0.05	0.01	0.005	0.001
TEST A UNA CODA	Z =	1.282	1.645	2.326	2.576	3.090
TEST A DUE CODE	Z =	1.645	1.960	2.576	2.813	3.291

1	BROMUS ERECTUS					
	90. 90. 80. 95. 80.					
	5. 0. 5. 5. 0.					
	450.00	45.00	-.2388	-.1111	-.631	

2	CAREX HUMILIS					
	25. 0. 35. 5. 25.					
	5. 35. 5. 30. 5.					
	SOMMA					
	MEDIA					
	INDICE OSS.					
	INDICE ATT.					
	TEST Z					

SOMMA	MEDIA	INDICE OSS.	INDICE ATT.	TEST Z
170.00	17.00	-.2278	-.1111	-.582

3	FESTUCA RUPICOLA							
	60.	80.	5.	10.	5.			
	70.	75.	20.	10.	5.			
	SOMMA		MEDIA			INDICE OSS.	INDICE ATT.	TEST Z
	340.00		34.00			.5506	-.1111	3.310

AUTOCORRELAZIONE SPAZIALE PER DATI QUANTITATIVI PUNTIFORMI

N. PUNTI = 8 N. ASSI = 2

IPOTESI NULLA DI RANDOMIZZAZIONE

LIVELLI DI SIGNIFICATIVITÀ		0.1	0.05	0.01	0.005	0.001
TEST A UNA CODA	Z =	1.282	1.645	2.326	2.576	3.090
TEST A DUE CODE	Z =	1.645	1.960	2.576	2.813	3.291

1	BROMUS ERECTUS							
	90.	90.	80.	10.	10.	10.	15.	20
	SOMMA		MEDIA			INDICE OSS.	INDICE ATT.	TEST Z
	325.00		40.63			.1740	-.1429	1.7573

2	CAREX HUMILIS							
	25.	90.	90.	90.	25.	60.	60.	60
	SOMMA		MEDIA			INDICE OSS.	INDICE ATT.	TEST Z
	500.00		62.50			-.1812	-.1429	-.2157

3	FESTUCA RUPICOLA							
	45.	35.	25.	60.	35.	45.	50.	55
	SOMMA		MEDIA			INDICE OSS.	INDICE ATT.	TEST Z
	350.00		43.75			-.0990	-.1429	.2489

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Address of the Author:
Dipartimento di Biologia
dell'Università di Trieste
I - 34100 Trieste, via A. Valerio 30

THE USE OF ELLIPSES OF EQUAL CONCENTRATION TO ANALYSE ORDINATION VEGETATION PATTERNS

Mario LAGONEGRO and Enrico FEOLI

Keywords: Ellipses, Forest, Ordination, Pattern, Structure.

Abstract: The use of ellipses of equal concentration is suggested for the analysis of pattern in ordination scattergrams produced directly by environmental variables, or with axes obtained by numerical methods. The potentials of the method are illustrated by some examples using structural characteristics of mixed forest type of NE Italy and environmental variables estimated by ecological indicator values.

Introduction

The analysis of vegetation patterns detected by ordination scattergrams can be done by the method suggested by Feoli & Ganis (1986). It consists in the use of a revised version of the Moran formula (Cliff & Ord, 1981) of autocorrelation for testing if the values of a variable, simple or composite, have a non-random pattern in the spaces defined by other ecological variables. The method does not give any information about the barycentre of the variable or about the correlation between the variables which define the space. We think that the method of ellipses of equal concentration (see Daboni, 1967; Mardia, Kent & Bibby, 1979) should constitute a further extension of the autocorrelation method in describing vegetation pattern related to ordination scattergrams.

The method

Given N points with coordinates (x_i, y_i) for $i = 1, \dots, N$, with which are associated N scores (p_i) of a variable i , the coordinates of the barycentre of the variable i in the space defined by the axes x and y are:

$$X_G = \frac{1}{T} \sum_{i=1}^N p_i x_i \quad Y_G = \frac{1}{T} \sum_{i=1}^N p_i y_i$$

where $T = \sum_{i=1}^N p_i$. The parameters of dispersion of x and y around the barycentre are:

$$s_x^2 = \sum_i^N \left(\frac{p_i}{T} \right) (x_i - X_G)^2$$

$$s_y^2 = \sum_i^N \left(\frac{p_i}{T} \right) (y_i - Y_G)^2$$

$$s_{xy} = \sum_i^N \left(\frac{p_i}{T} \right) (x_i - X_G) (y_i - Y_G)$$

$$R = \frac{s_{xy}}{s_x \cdot s_y}$$

R is the correlation coefficient. One can define the ellipse of equal concentration k as:

$$\frac{1}{1 - R^2} \left[\left(\frac{x - X_G}{s_x} \right)^2 - 2R \frac{(x - X_G)(y - Y_G)}{s_x \cdot s_y} + \left(\frac{y - Y_G}{s_y} \right)^2 \right] = k$$

$$|R| \neq 1$$

which is centered at (X_G, Y_G) with axes and inclination defined by s_x^2, s_y^2, R . It corresponds to the curve which, on the (x, y) plane, given a binormal distribution having the maximum at the barycentre, leaves outside itself a residual equal to $\exp(-k)$ (tail probability). It must be remembered that the total amounts to unity. It follows that if one wants an ellipse excluding 5% of the total binormal distribution, k must be estimated as:

$$e^{-k} = \frac{5}{100} = 0.05$$

$$k = -\ln 0.05$$

In general if a percentage P is to be excluded:

$$k_P = -\ln \left(\frac{P}{100} \right)$$

The corresponding ellipse will satisfy the following relation:

$$\left(\frac{x - X_G}{s_x} \right)^2 - 2R \left(\frac{x - X_G}{s_x} \cdot \frac{y - Y_G}{s_y} \right) + \left(\frac{y - Y_G}{s_y} \right)^2 = k_p (1 - R^2)$$

If

$$X_S = \frac{x - X_G}{s_x} \quad Y_S = \frac{y - Y_G}{s_y}$$

then:

$$X_S^2 - 2R X_S Y_S + Y_S^2 - k_p (1 - R^2) = 0$$

by reordering and taking X_S as an independent variable

$$Y_S^2 - (2R X_S) Y_S + [X_S^2 - k_p (1 - R^2)] = 0$$

$$a Y_S^2 + b Y_S + c = 0$$

where:

$$a = 1 \quad b = -2R X_S \quad c = X_S^2 - k_p (1 - R^2)$$

the solutions are real if:

$$b^2 - 4ac \geq 0$$

it follows that values of X_S may be derived from:

$$(X_S^2 - k_p) (1 - R^2) = 0$$

since $-1 < R < 1$ and consequently $(1 - R^2) \neq 0$

it follows that:

$$-\sqrt{k_p} \leq X_S \leq \sqrt{k_p}$$

and in consequence

$$X_G - s_x \sqrt{k_p} \leq x \leq X_G + s_x \sqrt{k_p}$$

The parameters computed in this way are used to compute the y values and to draw the ellipses.

When more than one group of objects is considered, or when a group is

considered under different weighting approaches, the ellipses can be computed for each group. The differences between the groups may be tested by Student's estimated as follows:

$$t = \frac{|D|}{S_{12}} \left[\frac{MN}{M+N} \right]^{1/2}$$

where:

$$D = [(X_{G1} - X_{G2})^2 + (Y_{G1} - Y_{G2})^2]^{1/2}$$

$$S_{12} = \left[\frac{(N-1)s_1^2 + (M-1)s_2^2}{M+N-2} \right]^{1/2}$$

$$s_1^2 = \left(\frac{s_x^2 + s_y^2}{2} \right)_1 \quad s_2^2 = \left(\frac{s_x^2 + s_y^2}{2} \right)_2$$

N being the number of objects in group 1, M that of group 2.

The program also computes the regression lines for each group and tests for differences between the population slopes and intercepts, two by two, (Zar, 1974).

The formulae are:

for slopes

$$t = \frac{|a_1 - a_2|}{S a_1 a_2}$$

$$S a_1 a_2 = \left[\frac{S_{xy}^2}{N \left(\sum_i x_i^2 \right)} + \frac{S_{xy}^2}{M \left(\sum_i x_i^2 \right)} \right]^{1/2}$$

$$S_{xy}^2 = \frac{\left[\sum_i^N y_i - \left(\sum_i^N x_i y_i \right) / \sum_i^N x_i^2 \right] + \left[\sum_i^M y_i - \left(\sum_i^M x_i y_i \right) / \sum_i^M x_i^2 \right]}{N + M - 4}$$

for elevations

$$t = \frac{(b_1 - b_2) - a_c (X_1 - X_2)}{\left\{ S_{xy}^2 \left[\frac{1}{N} + \frac{1}{M} + \frac{(X_1 - X_2)^2}{\left(\sum_i^N x_i^2 \right) + \left(\sum_i^M x_i^2 \right)} \right] \right\}^{1/2}}$$

$$a_c = \frac{(\sum_{i=1}^N x_i y_i) + (\sum_{i=1}^M x_i y_i)}{(\sum_{i=1}^N x_i^2) + (\sum_{i=1}^M x_i^2)}$$

The program ELLILOT (1), written both in GW-BASIC and FORTRAN 77 for personal computers operating under MS-DOS, is listed in the Appendix.

Examples

The method has been applied to data of mixed forest types obtained by Lagonegro and Feoli (1985) from Poldini (1982). They consist of two matrices describing 20 vegetation forest types. In one matrix the description of the types is based on the combination of life forms and growth forms (life-growth forms); in the other it is based on the average indicator values, Landolt (1977). The method of ranking characters proposed by Orlóci (1973) has been applied to the matrices, in order to select variables for the examples.

In the first place, the environmental variables as indicated by the average indicator values of the species were used as axes.

Among the environmental variables, humidity, temperature and pH have been chosen because they explain more than 90% of the total sum of squares. These variables, two at a time, served as axes to test for the pattern of all the life-growth forms. Among those with significant patterns (according to the autocorrelation method), we used those accounting for more than 90% of total sum of squares. They are: scapose hemicryptophytes, rhizome geophytes and suffrutescent chamaephytes.

In Figure 1 (a, b) is given an example of output of the program ELLILOT applied to the ordination scattergram with humidity and pH as axes, using the values of suffrutescent chamaephytes. Figure 1a shows the barycentre of the life-growth form in the space defined by humidity and pH, and the ellipses corresponding to 0.1, 1, 5, 31.7 percent tail probability. The regression line of the two variables is also printed.

Figure 1b shows the centroid of the two variables. The program also provides for the two figures to be drawn both on a graph as in Figure 2. In this case only two ellipses are drawn (those at 5% probability) to avoid excessive complexity.

The deviation of the centroid from the barycentre may be used as a measure of asymmetry of the pattern of the life-growth form with respect to the two variables used as ordination axes. The t test, estimated as described above, can serve as such a measure. In the case of Figure 2 the deviation of the barycentre from the centroid

(1) The program is included in a library (47 programs) written in GW-BASIC for personal computers running under MS-DOS operating system (Lagonegro & Feoli, 1985).

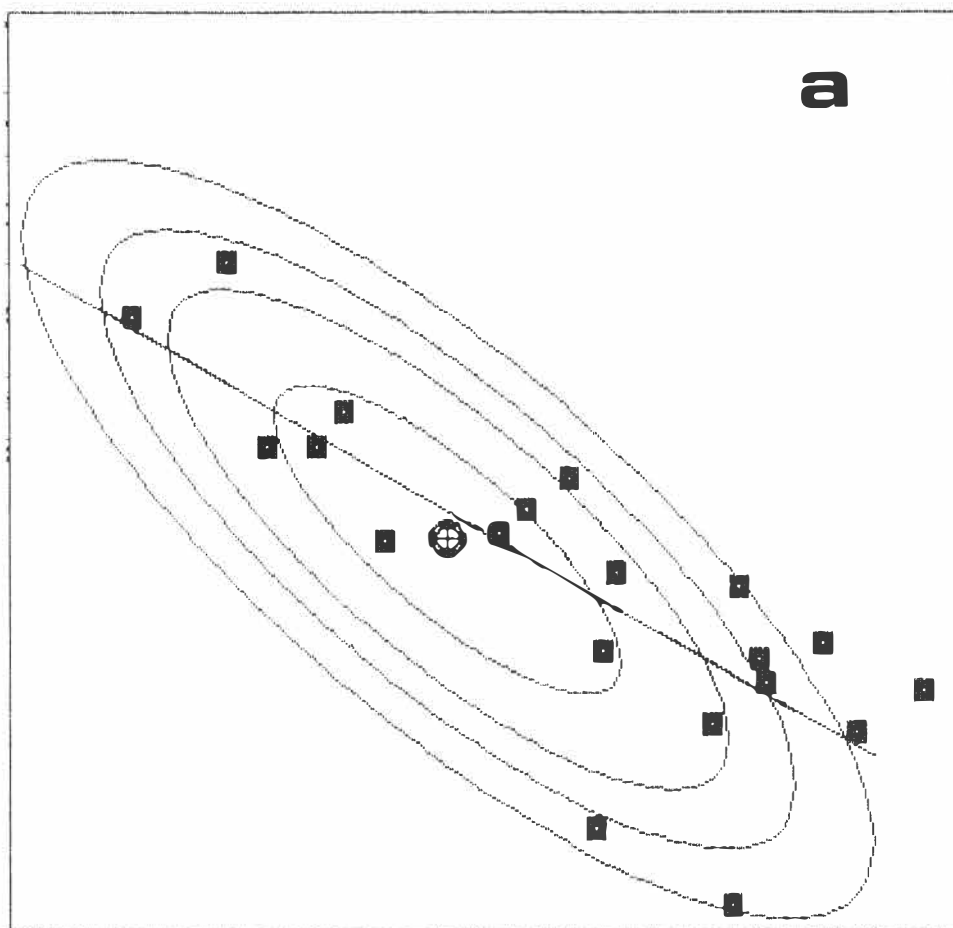


Fig. 1(a) — Ellipses of equal concentration drawn at probability levels of 0.317, 0.05, 0.01 and 0.001 with reference to the barycentre of suffrutescent chamaephytes.

is significant $t - p < 2\%$. This proves that the suffrutescent chamaephytes have a pattern that is asymmetric with respect to the centroid of the two variables. This does not happen for the other two life-growth forms.

The ellipses are useful in quantifying the pattern of a variable in ordination scattergrams. The pattern may be described by the cumulative frequencies of the points included in the ellipses corresponding to different probability levels, as in Table 1. The deviations from the expected frequencies, which can be calculated by multiplying the expected cumulative probability values by the total number of objects in the scattergram, may be used in a chi square test. From Table 1 one can conclude that the pattern deviating most from that expected is that of suffrutescent

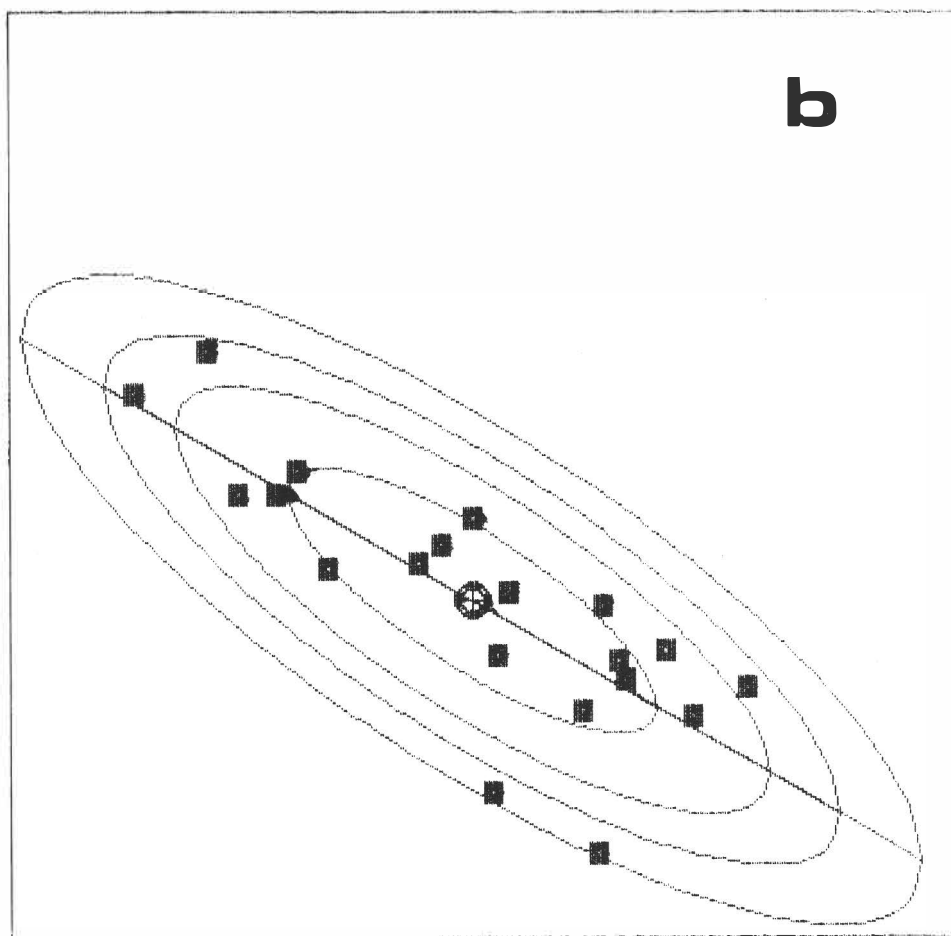


Fig. 1 (b) — Ellipses of equal concentration drawn at probability levels of 0.317, 0.05, 0.01 and 0.001 with reference to the centroid of the two variables defining the space: humidity and pH.

chamaephytes, followed by that of scapose hemicryptophytes. The pattern for rhizome geophytes does not deviate significantly from that expected. If one considers the two main groups of communities defined by the dendrogram of Figure 7 in Lagonegro & Feoli (1985), then one can see from Figure 3 that for cluster a there is no deviation from expectation, while for cluster b there is a significant deviation. This means that the cluster a represents a homogeneous environment for the suffrutescent chamaephytes as far as humidity and pH are concerned, while cluster b represents a heterogeneous environment. The regression lines corresponding to the two clusters suggest that they constitute two parallel series of vegetation with respect to humidity and pH. The distance between the barycentres of suffrutescent

(a)					
probability	0.317	0.05	0.01	0.001	chi square
expected	13.6	19	19.8	19.98	—
suffrutescent chamaephytes	4	10	15	17	12.70*
scapose hemicryptophytes	6	13	14	17	8.28*
rhizome geophyte	7	13	15	17	6.70

(b)					
probability	0.317	0.05	0.01	0.001	chi square
expected	13.6	19	19.8	19.98	—
suffrutescent chamaephytes	4	10	14	17	13.18*
scapose hemicryptophytes	6	14	14	17	7.70
rhizome geophytes	7	14	15	17	6.1

Table 1 — Cumulative frequency distributions of the 20 vegetation types, as shown by the pattern of their inclusion in four ellipses of equal concentration, respectively at probability levels of 0.317, 0.05, 0.01, 0.001. The ellipses are drawn with reference to the barycentre of the life-growth forms. The axes in (a) are humidity and pH and in (b) the first and second principal components of the matrix of seven environmental variables. The asterisk indicates that the frequency distribution deviates significantly from expectation (see the text).

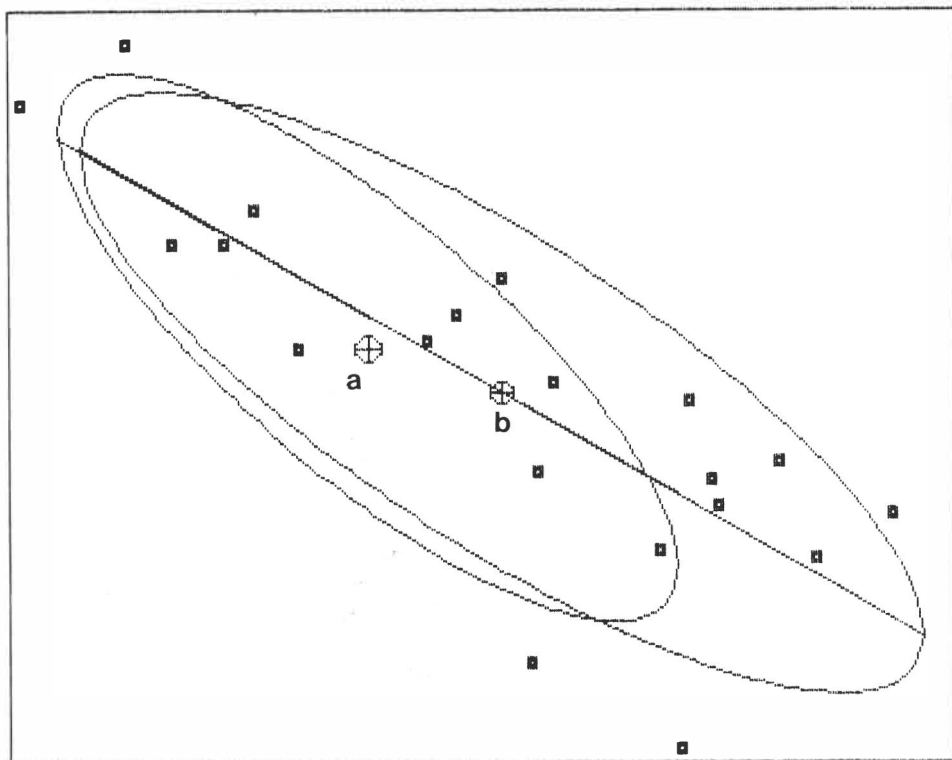


Fig. 2 — Ellipses of equal concentration at 0.05 probability drawn around the centroid (b) of the variables (humidity and pH) and around the barycentre (a) of suffrutescent chamaephytes. The distance between the barycentre and the centroid is significant ($p < 0.02$).

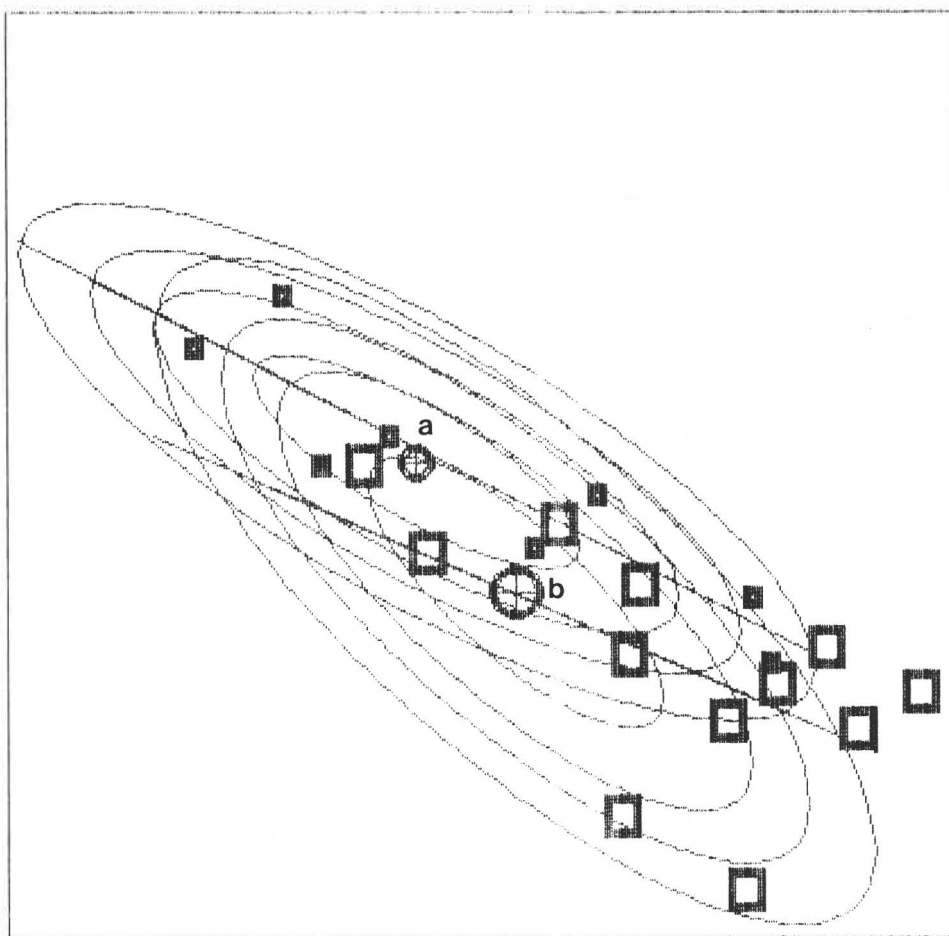


Fig. 3 — Ellipses of equal concentration at 0.317, 0.05, 0.01 and 0.001 probability around the barycentres of suffrutescent chamaephytes, computed for two clusters of forest types. Only the cumulative frequency distribution of the types of cluster a) fits expectation. The distance between the two barycentres is not significant.

chamaephytes is not significant; however the distance between the centroids of the two clusters is significant (Figure 4). The significant shift of the barycentre of cluster b from the centroid (Figure 5) proves further that the environment defined by such cluster is not homogeneous for suffrutescent chamaephytes. Figure 6 shows the ellipses of equal concentration for the cluster a and b at 5% probability in the space defined by temperature and humidity. The barycentres calculated for suffrutescent chamaephytes and the centroids of the clusters are indicated. The deviation of the barycentre from the centroid is significant only for cluster b, while the distance between the centroids and the distance between the barycentres of the

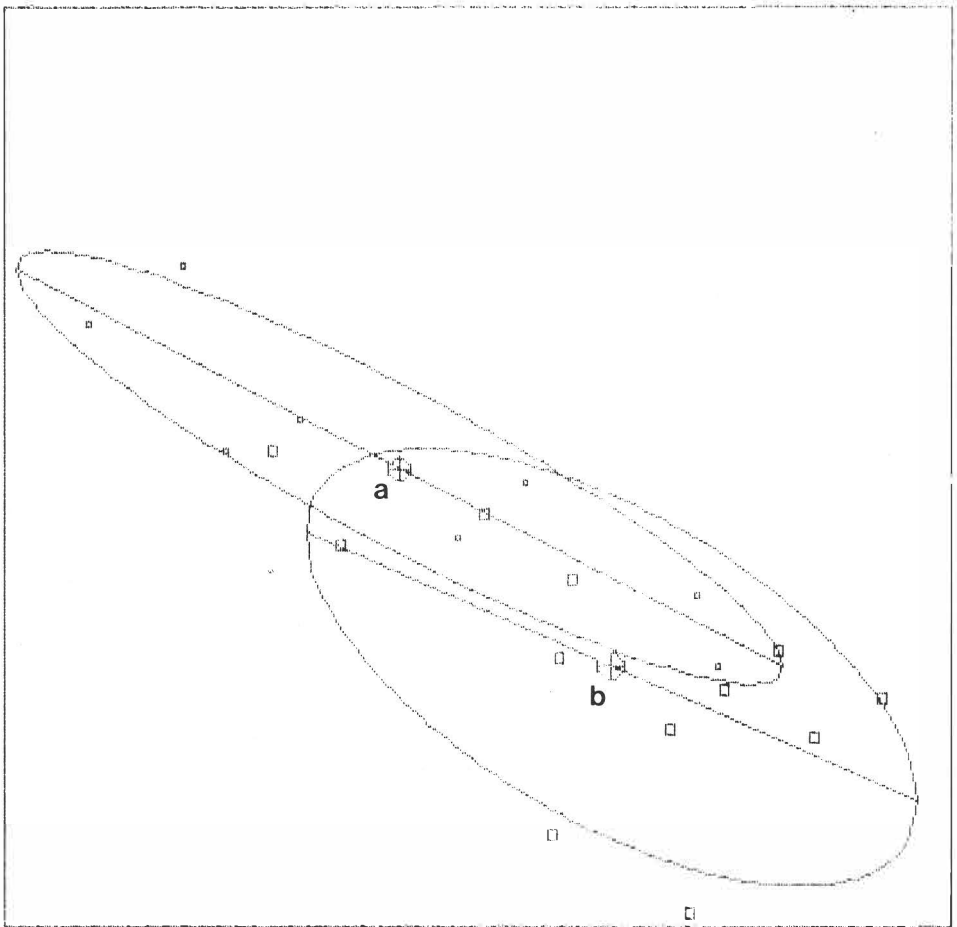


Fig. 4 — Ellipses of equal concentration, and regression lines, for two clusters of vegetation types a) and b) at the 5% level. The centroids of the clusters are drawn; the distance between them is significant ($p < 0.02$).

two clusters are significant. The relationship between temperature and humidity is linear for cluster a, while it is non-linear for cluster b.

Instead of the individual environmental variables, it seemed useful to use the axes of a principal components analysis as axes. This is illustrated by Figure 7 and Figure 8. In Figure 7 the centroids of cluster a and cluster b are significantly separated. Also in this figure the deviation of the barycentre of suffrutescent chamaephytes from the centroid is significant for cluster b, but not for cluster a. The space defined by the first two components of Figure 7 can be considered homogeneous for rhizome geophytes, but not for scapose hemicryptophytes or suffrutescent chamaephytes (see Table 1).

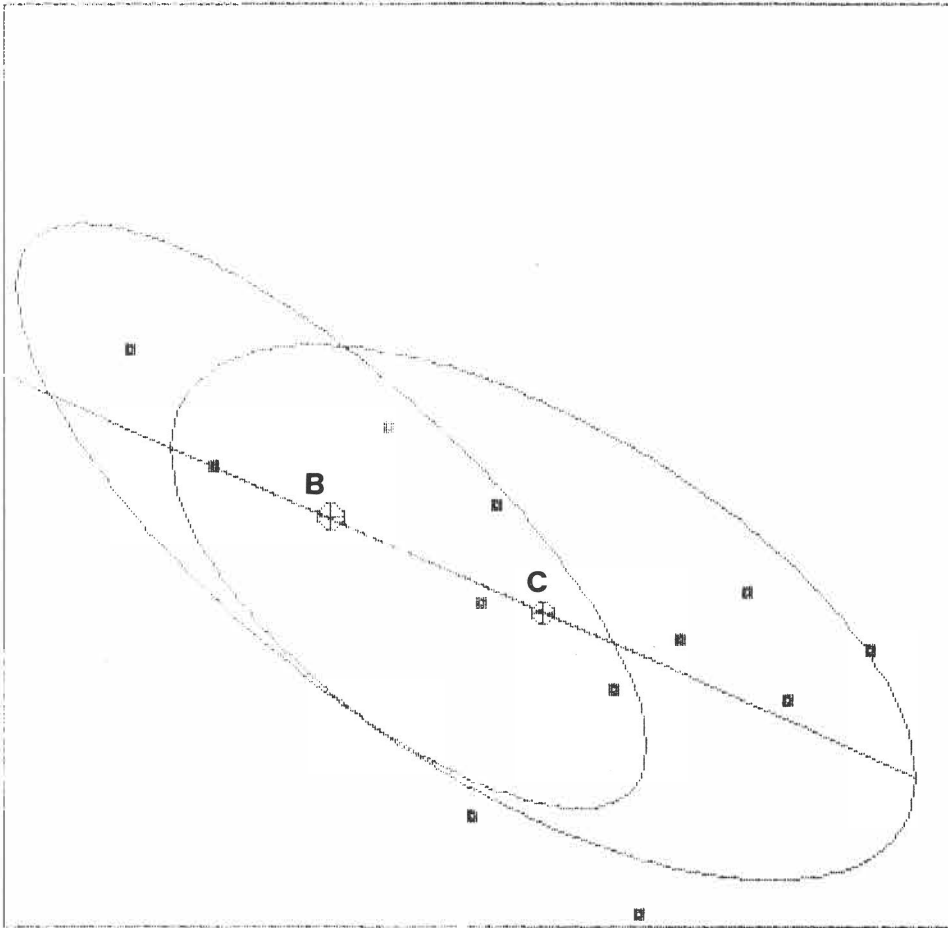


Fig. 5 — Ellipses of equal concentration around the barycentre B of suffrutescent chamaephytes of cluster b), and its centroid C, with reference to temperature and pH. The distance between the barycentre and centroid is significant ($p < 0.04$).

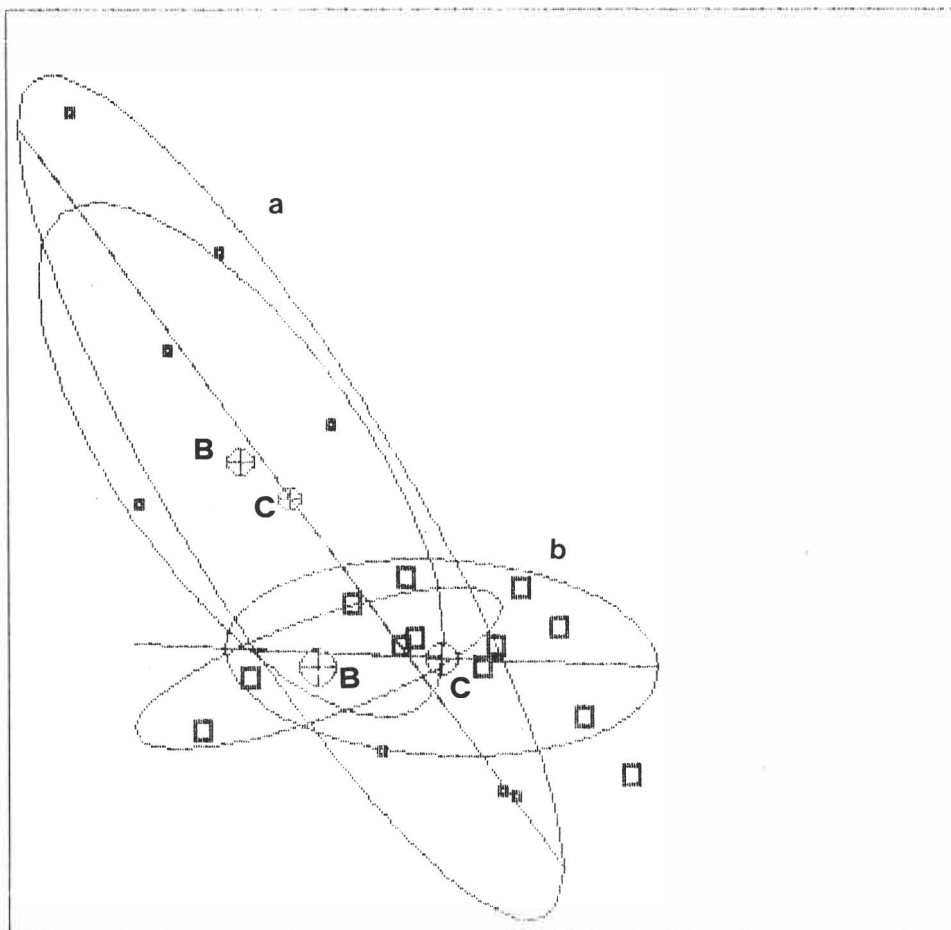


Fig. 6 — Ellipses of equal concentration at the 5% level around the centroids (C) and barycentres (B) of suffrutescent chamaephytes of clusters a) and b). The variables are humidity and temperature. The distances are significant between the barycentres of clusters a) and b), the centroids of cluster a) and b), the centroid of cluster a) and the barycentre of cluster b) and the centroid and barycentre of cluster b). The slopes of the regression lines are significantly different, while the intercepts are not.

In respect of the three life-growth forms, one can conclude that, in the space defined by the environmental variables and the 20 vegetation types, their niches (*sensu* Hutchinson, see Hurlbert, 1981) are shifting in an orderly fashion as one passes from the relatively, driest and most basic soils to the most humid and acid soils according to the sequence: suffrutescent chamaephytes, scapose hemi-cryptophytes and rhizome geophytes (Figure 8). In this sequence the barycentre of suffrutescent chamaephytes is significantly distant from the barycentres of the other two life-growth forms. The sequence corresponds also with decreasing

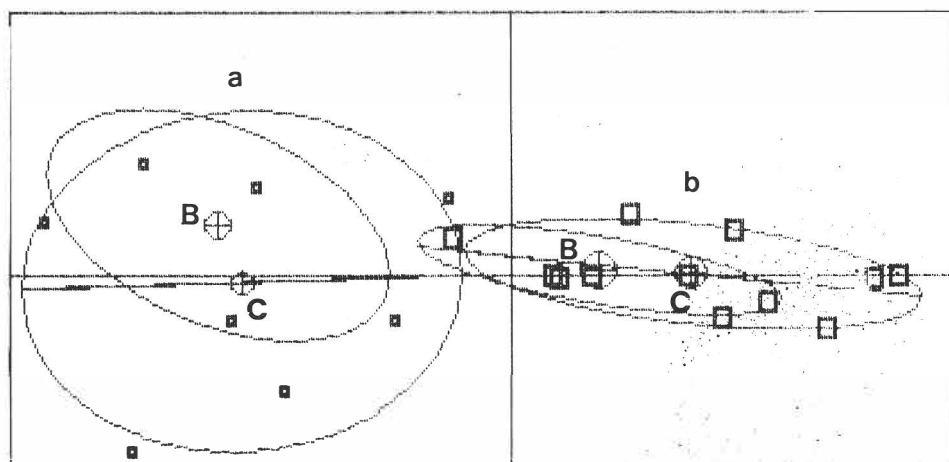


Fig. 7 — Ellipses of equal concentration at the 5% level around the centroids (C) and barycentres (B) of the clusters a) and b). The barycentres have been computed for suffrutescent chamaephytes. The variables are the first two components of the matrix describing the vegetation types by the eight average indicator values (see text).

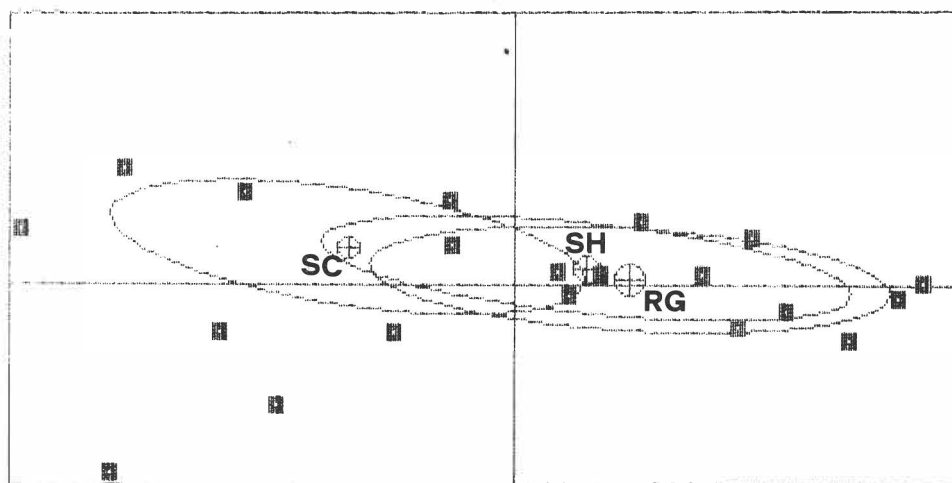


Fig. 8 — Ellipses of equal concentration at 31.7% around the barycentres of suffrutescent chamaephytes (SC), scapose hemicryptophytes (SH) and rhizome geophytes (RG). The variables are the same as in Figure 7.

temperature, light, and continentality and with increasing nutrients, the proportion of humus and silt and clay. This is proved by the correlation coefficients of the environmental variables with the first principal component of Figures 7 and 8. They are as follows: humidity 0.978, nutrients 0.93, humus 0.98, soil texture 0.93, pH -0.85 , light -0.96 , temperature -0.58 , continentality -0.60 .

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Authors' address:

Prof. Dr. E. Feoli

Prof. Dr. M. Lagonegro

Dipartimento di Biologia, Università degli Studi di Trieste, 34100 Italia

Appendix.

The data for the program must be prepared in a sequential file in which the information is contained in blocks of records, each block containing in order:

- 1) the alphanumeric code for the variable for which the analysis is required (type wanted);
- 2) the score for the variable (prod);
- 3) the scores of the variables which, two by two, define the space (variables); these may be several and their number is placed after the "prod" variable.

The following is an example of the data structure as printed:

(type wanted, prod, variables)					
casu	20	2.5	2.7	9.8	10.75
casu	10	0.9	1.3	6.9	9.88
casu	9	0.7	1.3	5.3	6.97

In this case there are 3 objects described by variable casu (type wanted), the scores of casu for the three objects, and the four variables which, two by two, define the spaces. The file must be typed as follows for both the BASIC and the FORTRAN versions:

```
casu
20
2.5
2.7
9.8
10.75
casu
10
0.9
1.3
6.9
9.88
casu
9
0.7
1.3
5.3
6.97
```

The listings of the program are given below, both in BASIC and FORTRAN.

```
10 REM-Program ELLIPL0T II (M.Lagonegro-1985)
20 OPTION BASE 1
30 ON ERROR GOTO 2010
40 INPUT"give n.lines,n.ellipses,n.vars in data table ";NL,NTY,NV
50 DIM TIPO$(NL),PROD(NL),VARS(NL,NV),PES1(NL),ELI(100,3,NTY),SLO(NTY),ES1(NTY),ES3(NTY),ES5(NTY),ELV(NTY)
60 DIM X(NL,NTY),Y(NL,NTY),R(NL,NTY),XG(NTY),YG(NTY),IKS1(NTY),IKS2(NTY),UN(NTY),S2(NTY),ES2(NTY)
70 INPUT"give filename for data ";DAF$
80 OPEN"i"#1,DAF$
90 FOR I=1 TO NL
100 INPUT#1, TIPO$(I)
110 INPUT#1, PROD(I)
120 FOR J=1 TO NV
130 INPUT#1, VARS(I,J)
140 NEXT J
150 NEXT I
160 CLOSE#1
170 INPUT"print data-y/n ";SN$
180 IF SN$="n" THEN 270
190 LPRINT" --- data table ---"
200 FOR I=1 TO NL
210 LPRINT TIPO$(I);PROD(I);
220 FOR J=1 TO NV
230 LPRINT VARS(I,J);
```

```

240 NEXT J
250 LPRINT
260 NEXT I
270 INPUT "give labels of couple of wanted vars-to stop give 0,0 ";N,M
280 K=1
290 IF M*N=0 THEN END
300 INPUT "type wanted/no ";TY$
310 IF TY$="no" THEN 270
320 INPUT "weighting-unif/prod ";TI$
330 PETOT=0
340 NU=0
350 FOR I=1 TO NL
360 A$=TIPO$(I)
370 IF A$(<)TY$ THEN 440
380 NU=NU+1
390 PESI(NU)=PROD(I)
400 X(NU,K)=VAR5(I,N)
410 Y(NU,K)=VAR5(I,M)
420 R(NU,K)=I
430 PETOT=PETOT+PROD(I)
440 NEXT I
450 UN(K)=NU
460 XG(K)=0
470 YG(K)=0
480 FOR I=1 TO NU
490 PESI(I)=PESI(I)/PETOT
500 IF TI$="unif" THEN PESI(I)=1/NU
510 XG(K)=XG(K)+X(I,K)*PESI(I)
520 YG(K)=YG(K)+Y(I,K)*PESI(I)
530 NEXT I
540 SX2=0
550 SY2=0
560 SXY=0
570 FOR I=1 TO NU
580 PES2=PESI(I)
590 SX2=SX2+PES2*(X(I,K)-XG(K))^2
600 SY2=SY2+PES2*(Y(I,K)-YG(K))^2
610 SXY=SXY+PES2*(X(I,K)-XG(K))*(Y(I,K)-YG(K))
620 NEXT I
630 SX=SQR(SX2)
640 SY=SQR(SY2)
650 S2(K)=(SX2+SY2)/2
660 R0=SXY/(SX*SY)
670 IF S2(K)=0 THEN LPRINT "Ellipse n.=",K
680 IF S2(K)=0 THEN LPRINT "sx=";SX;" sy=";SY;" ro=";R0
690 INPUT "give residual % ";REP
700 IF S2(K)=0 THEN LPRINT "residual %=";REP
710 REP=-LOG(REP/100)
720 IF R0=.99999 THEN R0=.99999
730 IF R0(-.99999 THEN R0=-.99999
740 X1=XG(K)-SQR(REP)*SX
750 X2=XG(K)+SQR(REP)*SX
760 DX=(X2-X1)/99
770 IK51(K)=X1
780 IK52(K)=X2
790 FOR I=1 TO 100
800 ELI(I,1,K)=DX*(I-1)+X1
810 X5=(ELI(I,1,K)-XG(K))/SX
820 B=-2*R0*X5
830 C=X5^2+REP*(R0^2-1)
840 BC=ABS(B^2-4*C)
850 Y51=.5*(-B-SQR(BC))
860 Y52=.5*(-B+SQR(BC))
870 ELI(I,2,K)=Y51*SY+YG(K)
880 ELI(I,3,K)=Y52*SY+YG(K)
890 NEXT I
900 IF S2(K)=0 THEN 1090
910 LPRINT "mode is ";TI$
920 LPRINT "x is ";N"-th var. and y is ";M;"-th"
930 LPRINT "x from ";X1;" to ";X2;" y from ";ELI(1,2,K);" to ";ELI(100,2,K)
940 LPRINT "centroid has X=";XG(K);" Y=";YG(K)
950 LPRINT " points have
960 FOR I=1 TO NU
970 LPRINT R(I,K); " x=";X(I,K); " y=";Y(I,K); " weight=";PESI(I)

```

```

980 NEXT I
990 NSCB=0:FOR I=1 TO NU-1:IF X(I,K)=(X(I+1,K) THEN 1040
1000 ACI=X(I,K):X(I,K)=X(I+1,K):X(I+1,K)=ACI
1010 ACI=Y(I,K):Y(I,K)=Y(I+1,K):Y(I+1,K)=ACI
1020 ACI=R(I,K):R(I,K)=R(I+1,K):R(I+1,K)=ACI
1030 NSCB=1
1040 NEXT I
1050 IF NSCB<>0 THEN 990
1060 LPRINT"horizontal sequence"
1070 FOR I=1 TO NU:LPRINT R(I,K);
1080 NEXT I:LPRINT
1090 K=K+1:IF K=NTY THEN 300
1100 INPUT"plot-scale factors diff/equal ";DIEQ$
1110 CLS:SCREEN 3
1120 NX=-1E+30
1130 MY=MX
1140 MNX=1E+30
1150 MNY=MNX
1160 FOR K=1 TO NTY
1170 NU=UN(K)
1180 FOR I=1 TO NU
1190 IF MX< X(I,K) THEN MX= X(I,K)
1200 IF MNX< X(I,K) THEN MNX= X(I,K)
1210 IF MY< Y(I,K) THEN MY= Y(I,K)
1220 IF MNY< Y(I,K) THEN MNY= Y(I,K)
1230 NEXT I:NEXT K
1240 FOR K=1 TO NTY
1250 FOR I=1 TO 100
1260 IF ELI(I,1,K) (MNX THEN MNX=ELI(I,1,K)
1270 IF ELI(I,1,K) (MX THEN MX=ELI(I,1,K)
1280 IF ELI(I,2,K) (MNY THEN MNY=ELI(I,2,K)
1290 IF ELI(I,2,K) (MY THEN MY=ELI(I,2,K)
1300 IF ELI(I,3,K) (MNY THEN MNY=ELI(I,3,K)
1310 IF ELI(I,3,K) (MY THEN MY=ELI(I,3,K)
1320 NEXT I: NEXT K
1330 LPRINT"x from ";MNX;" to ";MX;" y from ";MNY;" to ";MY
1340 FX=400/(MX-MNX)
1350 FY=320/(MY-MNY):IF DIEQ$="diff" THEN 1380
1360 IF FX=FY THEN FY=FX
1370 IF FY<FX THEN FX=FY
1380 LINE (0,49)-(420,399),B
1390 LPRINT"scale factors: fx=";FX;" fy=";FY
1400 XO=-MNX*FX+5
1410 YO=399+MNY*FY-5
1420 LINE (XO,49)-(XO,399)
1430 LINE (0,YO)-(420,YO)
1440 FOR K=1 TO NTY
1450 NU=UN(K)
1460 XX=(XG(K)-MNX)*FX+5
1470 YY=399-(YG(K)-MNY)*FY-5
1480 AR=K*4:UR=.83*AR:CIRCLE(XX,YY),AR
1490 LINE (XX-AR,YY)-(XX+AR,YY):LINE (XX,YY-UR)-(XX,YY+UR)
1500 FOR I=1 TO 100
1510 ELI(I,1,K)=(ELI(I,1,K)-MNX)*FX+5
1520 ELI(I,2,K)=399-(ELI(I,2,K)-MNY)*FY-5
1530 ELI(I,3,K)=399-(ELI(I,3,K)-MNY)*FY-5
1540 NEXT I
1550 LINE (ELI(1,1,K),ELI(1,2,K))-(ELI(1,1,K),ELI(1,3,K))
1560 FOR I=2 TO 100
1570 X1=ELI(I-1,1,K)
1580 X2=ELI(I,1,K)
1590 Y1=ELI(I-1,2,K)
1600 Y2=ELI(I,2,K)
1610 Y3=ELI(I-1,3,K)
1620 Y4=ELI(I,3,K)
1630 LINE (X1,Y1)-(X2,Y2)
1640 LINE (X1,Y3)-(X2,Y4)
1650 NEXT I
1660 LINE (ELI(100,1,K),ELI(100,2,K))-(ELI(100,1,K),ELI(100,3,K))
1670 FOR I=1 TO NU
1680 XX=(X(I,K)-MNX)*FX+5
1690 YY=399-(Y(I,K)-MNY)*FY-5
1700 LINE (XX-K,YY-K)-(XX+K,YY+K),B

```

```

1710 NEXT I
1720 S1=0:S2=0:S3=0:S4=0:S5=0
1730 FOR I=1 TO NU:S1=S1+X(I,K)^2:S2=S2+X(I,K):S3=S3+X(I,K)*Y(I,K):S4=S4+Y(I,K):S5=S5+Y(I,K)^2:NEXT I
1740 PEND=(NU*S3-S2*S4)/(NU*S1-S2^2):TNOT=(S4-S2*PEND)/NU
1750 X=IKS1(K):Y=PEND*X+TNOT:XX=(X-MNX)*FX+5:YY=399-(Y-MNY)*FY-5:X=IKS2(K):Y=PEND*X+TNOT
1760 XXX=(X-MNX)*FX+5:YYY=399-(Y-MNY)*FY-5:LINE (XX,YY)-(XXX,YYY)
1770 IF SN#="y" THEN LPRINT"regression line: ";PEND;"*x "CHR$(44-SGN(TNOT)):ABS(TNOT)
1780 SLO(K)=PEND:ES1(K)=S1:ES2(K)=S2:ES3(K)=S3:ES5(K)=S5:ELV(K)=TNOT:NEXT K
1790 LOCATE,55:INPUT"plot on printer-y/n ";MAH$
1800 IF MAH#="y" THEN LCOPY 0
1810 IF NTY=1 THEN 1980
1820 LPRINT:LPRINT" *** Comparison among centroids,slopes & intercepts ***":LPRINT
1830 FOR K=1 TO NTY-1:FOR J=K+1 TO NTY:N=UN(K):M=UN(J)
1840 ST2=((M-1)*S2(K)+(M-1)*S2(J))/(M+N-2)
1850 D=SQR((XG(K)-XG(J))^2+(YG(K)-YG(J))^2):TI=D*SQR(M*N/(ST2*(M+N)))
1860 T=TI:DF=M+N-4:GOSUB 2030
1870 LPRINT"pair ";K;" and ";J;" --- t=";TI;" deg.of freedom=";DF;" prob(Z)=";A
1880 RESS1=ES5(K)-(ES3(K)^2)/ES1(K):RESS2=ES5(J)-(ES3(J)^2)/ES1(J)
1890 ES2XY=(RESS1+RESS2)/(M+N-4):S8182=SQR(ES2XY/ES1(K)+ES2XY/ES1(J))
1900 TI=ABS(SLO(K)-SLO(J))/S8182:T=TI:DF=M+N-4:GOSUB 2030
1910 LPRINT" slopes t'=";TI;" d.freedom=";DF;" with prob(Z)=";A
1920 BICI=(ES3(K)+ES3(J))/(ES1(K)+ES1(J)):ME1=ES2(K)/N:ME2=ES2(J)/N:DIME=ME1-ME2
1930 BOH=DIME^2/(ES1(K)+ES1(J)):TI=(ELV(1)-ELV(2)-BICI*(DIME))/SQR(ES2XY*(1/N+1/M+BOH)):TI=ABS(TI)
1940 DF=M+N-3:T=TI:GOSUB 2030
1950 LPRINT" intercpts t'=";TI;" d.freedom=";DF;" with prob(Z)=";A
1970 NEXT J:LPRINT: NEXT K
1980 CLS
1990 GOTO 270
2000 END
2010 PRINT"kapelmeister n.";ERR;" line n.";ERL
2020 END
2030 REM-Subroutine Probt
2040 T=ATN(T/SQR(DF)): IF DF=1 THEN A=.5-T/3.14159
2050 IF DF=2 THEN A=.5*(1-SIN(T))
2060 IF DF=3 THEN A=.5-(1/3.14159)*(T+COS(T))*SIN(T)
2070 IF DF<4 THEN GOTO 2180
2080 IF DF/2)INT(DF/2) THEN 2140
2090 C=1:Q=2
2100 U=1:FOR I=2 TO Q STEP 2:U=U*(I-1)/I
2110 NEXT I:C=C+U*(ABS(COS(T)))^Q
2120 Q=Q+2:IF Q<DF THEN 2100
2130 A=.5*(1-(SIN(T))*C):GOTO 2180
2140 C=1:Q=2
2150 U=1:FOR I=2 TO Q STEP 2:U=U*I/(I+1):NEXT I
2160 C=C+U*(ABS(COS(T)))^Q:Q=Q+2:IF Q<DF-1 THEN 2150
2170 A=.5-(1/3.14159)*(T+COS(T))*SIN(T)*C
2180 A=A*200
2190 RETURN

```

```

$LARGE
PROGRAM ELLIDIS
C---DRAWS EQUI-CONCENTRATION ELLIPSES FOR OBJECTS DESCRIBED
C---BY PAIRS OF VARIABLES-COMPARES THEN REGRESSION LINES
C---WRITTEN BY M.LAGONEGRO-1986 (FROM BASIC VERSION)
COMMON SLO(25),ELV(25),ES1(25),ES2(25),ES3(25),ES5(25),NL,NTV
1,NV,PROD(200),VARS(200,25),PESI(200),ELI(100,3,25)
2X(200,25),Y(200,25),IR(200,25),XG(25),YG(25),EKSI(25)
3,EKS2(25),KUN(25),S52(25)
CHARACTER *4TIPO(200),ADO,TIDO,SNOO,TISO,DIEQS
CHARACTER *10DAFDO
WRITE(*,*)' GIVE N.LINES,N.ELLIPSES,N.VARIABLES'
READ(*,*)NL,NTV,NV
WRITE(*,*)' GIVE FILENAME OF DATA'
READ(*,')(A10)'DAFDO
OPEN(1,FILE=DAFDO,STATUS='OLD')
DO 10120 I=1,NL
  READ(1,')(A4)'TIPO(I)
  READ(1,*)PROD(I)
  DO 10120 J=1,NV
10120  READ(1,*)VARS(I,J)
    CLOSE(1)
    WRITE(*,*)' PRINT DATA-V/N'
    READ(*,')(A4)'SNOO
    IF(SNOO.EQ.'N')GOTO 10260
    WRITE(*,*)' --- DATA TABLE ---'
    DO 10200 I=1,NL
10200  WRITE(*,1)TIPO(I),PROD(I),(VARS(I,J),J=1,NV)
    1 FORMAT(1X,A4,G11.4,(1X,10G10.3))
10260  WRITE(*,*)' GIVE INDEXES OF WANTED VARS-TO STOP GIVE 0,0'
    READ(*,*)N,M
    K=1
    IF(M.EQ.0)STOP
10290  WRITE(*,*)' TYPE WANTED/N'
    READ(*,')(A4)'TIDO
    IF(TIDO.EQ.'N')GOTO 10260
    WRITE(*,*)' WEIGHTING-UNIF/PROD'
    READ(*,')(A4)'TISO
    PETOT=0
    NU=0
    DO 10430 I=1,NL
      ADO=TIPO(I)
      IF(ADO.NE.TIDO)GOTO 10430
      NU=NU+1
      PESI(NU)=PROD(I)
      X(NU,K)=VARS(I,N)
      Y(NU,K)=VARS(I,M)
      IR(NU,K)=I
      PETOT=PETOT+PROD(I)
10430  CONTINUE
      KUN(K)=NU
      XG(K)=0
      YG(K)=0
      DO 10510 I=1,NU
        PESI(I)=PESI(I)/PETOT
        IF(TISO.EQ.'UNIF')PESI(I)=1./FLOAT(NU)
        XG(K)=XG(K)+X(I,K)*PESI(I)
10510  YG(K)=YG(K)+Y(I,K)*PESI(I)
        SX2=0
        SY2=0
        SXV=0
        DO 10600 I=1,NU
          PES2=PESI(I)
          SX2=SX2+PES2*(X(I,K)-XG(K))**2
          SY2=SY2+PES2*(Y(I,K)-YG(K))**2
10600  SXV=SXV+PES2*(X(I,K)-XG(K))*(Y(I,K)-YG(K))
          SX=SQRT(SX2)
          SY=SQRT(SY2)
          S52(K)=(SX2+SY2)/2
          RO=SXV/(SX*SY)
          IF(SNOO.EQ.'V')WRITE(*,*)' ELLIPSE N,=',K
          IF(SNOO.EQ.'V')WRITE(*,*)' SX=',SX,' SY=',SY,' RO=',RO
          WRITE(*,*)' GIVE RESIDUAL(Z)'

```

```

READ(*,*)REP
IF(SND0.EQ,'V')WRITE(*,*)' RESIDUAL Z=',REP
REP=-LOG(REP/100)
IF(R0.GT.(.99999))R0=.99999
IF(R0.LT.(-.99999)) R0=-.99999
X1=XG(K)-SQRT(REP)*SX
X2=XG(K)+SQRT(REP)*SX
DX=(X2-X1)/99.
EK51(K)=X1
EK52(K)=X2
DO 10870 I=1,100
  ELI(I,1,K)=DX*(I-1)+X1
  XS=(ELI(I,1,K)-XG(K))/SX
  B=-2.*R0*XS
  C=XS**2+REP*(R0**2-1.)
  BC=ABS(B**2-4.*C)
  YS1=.5*(-B-SQRT(BC))
  YS2=.5*(-B+SQRT(BC))
  ELI(I,2,K)=YS1*SV+VG(K)
  ELI(I,3,K)=YS2*SV+VG(K)
  IF(SND0.EQ,'N')GOTO 11180
  WRITE(*,2)TISO
2  FORMAT(' MODE IS:',A4)
  WRITE(*,3)N,M
3  FORMAT(' X IS ',I4,'-TH VAR. Y IS ',I4,'-TH')
  WRITE(*,4)X1,X2,ELI(1,2,K),ELI(100,2,K)
4  FORMAT(' X FROM:',G11.4,' TO:',G11.4,' Y FROM:',G11.4,' TO:',
1G11.4)
  WRITE(*,5)XG(K),YG(K)
5  FORMAT(' CENTROID HAS X=',G11.4,' Y=',G11.4)
  WRITE(*,*)' POINTS HAVE'
DO 10960 I=1,NU
10960 WRITE(*,6)IR(I,K),X(I,K),Y(I,K),PESI(I)
6  FORMAT(' POS.IN TAB.=',I4,' X=',G11.4,' Y=',G11.4,' WEIGHT='
1,G11.4)
10980 NSCB=0
DO 11110 I=1,NU-1
  IF(X(I,K).LE.X(I+1,K))GOTO 11110
  ACI=X(I,K)
  X(I,K)=X(I+1,K)
  X(I+1,K)=ACI
  ACI=Y(I,K)
  Y(I,K)=Y(I+1,K)
  Y(I+1,K)=ACI
  IACI=IR(I,K)
  IR(I,K)=IR(I+1,K)
  IR(I+1,K)=IACI
  NSCB=1
11110 CONTINUE
  IF(NSCB.NE.0)GOTO 10980
  WRITE(*,*)' HORIZONTAL SEQUENCE'
DO 11150 I=1,NU
11150 WRITE(*,7)IR(I,K)
7  FORMAT('X,2014')
11180 K=K+1
  IF(K.LE.NTY)GOTO 10290
  WRITE(*,*)' GIVE PLOT-SCALE FACTOR:DIFF/EQUA'
  READ(*,*){A4}'DIEQS
  RMX=-1.E+30
  RMV=RMX
  RMNX=1.E+30
  RMNV=RMNX
  DO 11350 K=1,NTY
    NU=KUN(K)
    DO 11340 I=1,NU
      IF(RMX.LT.X(I,K)) RMX= X(I,K)
      IF(RMNX.GT.X(I,K)) RMNX= X(I,K)
      IF(RMV.LT.Y(I,K)) RMV= Y(I,K)
      IF(RMNV.GT.Y(I,K)) RMNV= Y(I,K)
11340 CONTINUE
11350 CONTINUE
    DO 11450 K=1,NTY
      DO 11440 I=1,100

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```

      IF(ELI(I,1,K).LT.RMN)RMN=ELI(I,1,K)
      IF(ELI(I,1,K).GT.RMX)RMX=ELI(I,1,K)
      IF(ELI(I,2,K).LT.RMNY)RMNY=ELI(I,2,K)
      IF(ELI(I,2,K).GT.RMV)RMV=ELI(I,2,K)
      IF(ELI(I,3,K).LT.RMNV)RMNV=ELI(I,3,K)
      IF(ELI(I,3,K).GT.RMY)RMY=ELI(I,3,K)
11440  CONTINUE
11450  CONTINUE
      WRITE(*,9)RMN,RMX,RMNY,RMV
9      FORMAT(' X FROM',G11.4,' TO',G11.4,' -- Y FROM',G11.4,' TO'
1,G11.4)
      FX=100/(RMX-RMN)
      FV=100/(RMV-RMNY)
      IF(DIEQS.EQ.'DIFF')GOTO 11520
      IF(FX.LE.FV) FV=FX
      IF(FV.LE.FX) FX=FV
11520  CALL PLONPA(RMN,RMX,RMNY,RMV,FX,FV,SND0)
      IF(NTV.EQ.1)GOTO 12640
      WRITE(*,*)'D * COMPARISON FOR CENTROIDS,SLOPES,INTERCEPTS'
      DO 12630 K=1,NTV-1
      DO 12610 J=K+1,NTV
      M=KUN(K)
      N=KUN(J)
      ST2=(FLOAT(N-1)*S52(K)+FLOAT(M-1)*S52(J))/FLOAT(M+N-2)
      D=SQRT((XG(K)-XG(J))**2+(YG(K)-YG(J))**2)
      TI=D*SQRT(FLOAT(M*N)/(ST2*FLOAT(M+N)))
      T=TI
      DF=M+N-4
      CALL PROBT(T,DF,A)
      WRITE(*,10)K,J,TI,DF,A
10     FORMAT(' PAIR ',I4,' & ',I4,' -- T=',G11.4,' D.FR.',F6.0,
1' HO PROB.(Z)=' ,G11.4)
      RESS1=E53(K)-(E53(K)**2)/E51(K)
      RESS2=E53(J)-(E53(J)**2)/E51(J)
      ES2XY=(RESS1+RESS2)/FLOAT(N+M-4)
      SB1B2=SQRT(ES2XY/E51(K)+ES2XY/E51(J))
      TI=ABS(SLO(K)-SLO(J))/SB1B2
      T=TI
      DF=M+N-4
      CALL PROBT(T,DF,A)
      WRITE(*,11)TI,DF,A
11     FORMAT(' SLOPES T=',G11.4,' D.FR.',F6.0,' HO PROB.(Z)='
1,G11.4)
      BICI=(E53(K)+E53(J))/(E51(K)+E51(J))
      AME1=E52(K)/FLOAT(N)
      AME2=E52(J)/FLOAT(M)
      DIME=AME1-AME2
      BOH=DIME**2/(E51(K)+E51(J))
      TI=(ELV(1)-ELV(2)-BICI*(DIME))/SQRT(ES2XY*(1./FLOAT(N)+
11./FLOAT(M)+BOH))
      TI=ABS(TI)
      DF=M+N-3
      T=TI
      CALL PROBT(T,DF,A)
      WRITE(*,12)TI,DF,A
12     FORMAT(' INTCP TS T=',G11.4,' D.FR.',F6.0,' HO PROB.(Z)='
1,G11.4)
12610  CONTINUE
      WRITE(*,*)' *
12630  CONTINUE
12640  CONTINUE
      GOTO 10260
      END
      SUBROUTINE PROBT(T,DF,A)
      T=ATAN(T/SQRT(DF))
      IF(DF.EQ.1.) A=.5-T/3.14159
      IF(DF.EQ.2.) A=.5*(1.-SIN(T))
      IF(DF.EQ.3.) A=.5-(1./3.14159)*(T+COS(T)*SIN(T))
      IF(DF.LT.4.) GOTO 12970
      IF((DF/2.).GT.INT(DF/2.))GOTO 12870
      C=1.
      Q=2.
12780  U=1.

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      IQU=Q+.5
      DO 12800 I=2, IQU, 2
12800  U=U*FLOAT(I-1)/FLOAT(I)
        C=C+U*(ABS(COS(T)))*Q
        Q=Q+2.
        IF (Q.LT.DF) GOTO 12780
        A=.5*(1.-(SIN(T))*C)
        GOTO 12970
12870  C=1.
        Q=2.
12890  U=1.
        IQU=Q+.5
      DO 12910 I=2, IQU, 2
12910  U=U*FLOAT(I)/FLOAT(I+1)
        C=C+U*(ABS(COS(T)))*Q
        Q=Q+2.
        IF (Q.LT.(DF-1.)) GOTO 12890
        A=.5*(1./3.14159)*(T+COS(T)*SIN(T)*C)
12970  A=A*200.
      RETURN
      END

      SUBROUTINE PLONPA(RMNX,RMX,RMNY,RMY,FX,FY,SND0)
      COMMON SLO(25),ELV(25),ES1(25),ES2(25),ES3(25),ES5(25),NL,NTY
      1,NU,PROD(200),VARS(200,25),PESI(200),ELI(100,3,25),
      2X(200,25),Y(200,25),IR(200,25),XG(25),VG(25),EK51(25)
      3,EK52(25),KUN(25),S52(25)
      CHARACTER*102,102
      CHARACTER*45SND0
      DO 100 I=1,102
      DO 100 J=1,102
100    PLOT(I,J)=CHAR(32)
      DO 101 I=1,102
      PLOT(1,I)=CHAR(45)
      PLOT(102,I)=CHAR(45)
      PLOT(I,1)=CHAR(33)
101    PLOT(I,102)=CHAR(33)
      WRITE(*,1)FX,FY
      1  FORMAT(' SCALE FACTORS - FX=',G11.4,' FY=',G11.4)
      XO=-RMNX*FX+1.
      YO=102.-RMNY*FY-1.
      CALL LINE(XO,1.,XO,102.,PLOT,33)
      CALL LINE(1.,YO,102.,YO,PLOT,45)
      DO 12220 K=1,NTY
      NU=KUN(K)
      DO 11710 I=1,100
      ELI(I,1,K)=(ELI(I,1,K)-RMNX)*FX+1.
      ELI(I,2,K)=102.-(ELI(I,2,K)-RMNY)*FY-1.
11710  ELI(I,3,K)=102.-(ELI(I,3,K)-RMNY)*FY-1.
      DO 11820 I=1,100
      X2=ELI(I,1,K)
      Y2=ELI(I,2,K)
      Y4=ELI(I,3,K)
      IX2=X2+.5
      IY2=Y2+.5
      IV4=Y4+.5
      PLOT(IY2,IX2)=CHAR(42)
11820  PLOT(IV4,IX2)=CHAR(42)
      S1=0.
      S2=0.
      S3=0.
      S4=0.
      S5=0.
      DO 12000 I=1,NU
      S1=S1+X(I,K)**2
      S2=S2+X(I,K)
      S3=S3+X(I,K)*Y(I,K)
      S4=S4+Y(I,K)
12000  S5=S5+Y(I,K)**2
      PEND=(FLOAT(NU)*S3-S2*S4)/(FLOAT(NU)*S1-S2**2)
      TN0T=(S4-S2*PEND)/FLOAT(NU)
      AX=EKS1(K)
      AY=PEND*AX+TN0T
      XX=(AX-RMNX)*FX+1.

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YY=102.-(AY-RMNV)*FY-1.
AX=EKS2(K)
AY=PEND*AX+TNOT
XXX=(AX-RMNK)*FX+1.
YYV=102.-(AY-RMNV)*FY-1.
CALL LINE(XX,YY,XXX,YYV,PLOT,43)
IF(SND0.EQ.'Y') WRITE(*,*) 'REGRESSION LINE:'
WRITE(*,2)PEND,TNOT
2  FORMAT(' SLOPE=',G11.4,' INTERCEPT=',G11.4)
SLO(K)=PEND
ES1(K)=S1
ES2(K)=S2
ES3(K)=S3
ES5(K)=S5
ELV(K)=TNOT
DO 11880 I=1,NU
  XX=(X(I,K)-RMNX)*FX+1.
  YY=102.-(Y(I,K)-RMNV)*FY-1.
  IXX=XX+.5
  IYV=YY+.5
11880 PLOT(IYV,IXX)=CHAR(64+K)
  XX=(XG(K)-RMNX)*FX+1.
  YY=102.-(YG(K)-RMNV)*FY-1.
  IXX=XX+.5
  IYV=YY+.5
  PLOT(IYV,IXX)=CHAR(35)
12220 CONTINUE
  WRITE(*,*) ' PLOT ON PRINTER-Y=1/N=D'
  READ(*,*)MAH
  IF(MAH.EQ.D)RETURN
  DO 3 I=1,102
3  WRITE(*,4)(PLOT(I,J),J=1,102)
4  FORMAT(1X,102A1)
  RETURN
END
SUBROUTINE LINE(X1,Y1,X2,Y2,PLOT,NC)
CHARACTER PLOT(102,102)
DX=X2-X1
DY=Y2-Y1
IF(DX.EQ.D.)DX=1.E-9
A=DY/DX
B=Y1-A*X1
PA=DX/100
DO 5 I=1,101
  XX=X1+(I-1)*PA
  YY=A*XX+B
  IF(X1.EQ.X2)YY=I
  IF(Y1.EQ.Y2)XX=I
  IXX=XX+.5
  IYV=YY+.5
  IF(IXX.GT.102.OR.IXX.LT.1)IXX=1
  IF(IYV.GT.102.OR.IYV.LT.1)IYV=1
5  PLOT(IYV,IXX)=CHAR(NC)
  RETURN
END

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